EDB Postgres AI for WarehousePG

Version 7.4

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1 EDB Postgres AI for WarehousePG

Introducing WarehousePG

WarehousePG is a new Apache 2-licensed fork of the formerly open source Greenplum Database. It offers binary compatibility with the legacy Greenplum versions most widely deployed by customers (6.x and 7.x) — plus net-new functionality and integrations.

Key features

- Petabytes scale with high-speed /-concurrency performance, via MPP Cluster topology with a Postgres fork based on PG 12.12.
- A Master (coordinator) for query optimization and parallel plan and distribution
- Multiple segments (workers) for parallel execution of queries with each segment being a Postgres instance.
- High availability with standbys for the Master and mirrors for the segments.
- High-speed interconnections for continuous data processing pipelining.

Support

For business-critical workloads, EDB Postgres AI provides support for WarehousePG. See the EDB Postgres AI support for Greenplum workloads page for more information.

Documentation

This section is adapted from the WarehousePG v7.x documentation.

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2 WarehousePG 7.x release notes

The WarehousePG documentation describes the latest version of WarehousePG 7.

Version	Release date
7.4.0-WHPG	7 April 2026
7.3.1-WHPG	30 January 2026
7.3.0-WHPG	14 November 2025
7.2.2-WHPG	17 November 2025
7.2.1-WHPG	15 May 2025

WarehousePG 7.4.0-WHPG

Released: 7 April 2026

WarehousePG 7.4.0-WHPG includes the following new features, enhancements, bug fixes, and other changes:

New features

- Introduced `pg_stat_statements` for WarehousePG, extending standard PostgreSQL statistics collection to include all segment nodes.
- Implemented `DISTRIBUTED COORDINATOR ONLY` tables to allow metadata to reside exclusively on the coordinator node, supporting specialized use cases where extensions must access data during early-stage query processing before distributed execution begins.

Enhancements

- Added automatic fallback to the Postgres planner when `vchord` indexes are present.
- Simplified the `gp_stat_progress_copy_summary` view and corrected issues where `NULL` values were improperly handled.
- Enabled the `get_ao_compression_ratio()` function to execute in query executors.
- Optimized internal cluster communications by improving the performance of Interconnect (IC) UDP processes and eliminating stale file descriptor warnings, resulting in more stable and faster data exchange between nodes.

Bug fixes

- Improved query planner accuracy for anti-joins and left anti-semi joins by resolving a double-calculation error in join selectivity. This fix resolves issues where underestimated join costs led to inefficient query plans, resulting in significantly faster performance for complex analytical workloads.
- Resolved critical stability issues in the ORCA optimizer, including fixes for segmentation faults, infinite recursion, and improper motion creation on QE slices.
- Fixed ORCA `regr_count` scalar subquery decorrelation to prevent planning errors during complex aggregations.
- Resolved an issue where ORCA failed to handle views with unused CTEs after changes were made to underlying table structures.
- Improved DXL translation by fixing the handling of required but unused columns.
- Fixed `gpcheckcat` inconsistencies encountered when using the SCRAM-SHA-256 authentication algorithm.
- Ensured `initdb` only evaluates `errno` when a system call explicitly fails, preventing successful directory operations from being incorrectly reported as errors due to residual error codes from previous tasks.
- Ensured `isolation2` test compatibility for Python 3.14 by explicitly setting the subprocess start method to `fork`, preventing `cannot pickle TextIOWrapper` errors caused by the change in Python's default process spawning behavior on Linux.

Security

- Mitigated SQL injection risks in `pg_dump` and `pg_dumpall` for CVE-2025-8715 by ensuring object names containing newlines are properly sanitized before being written as comments in backup files, preventing a vulnerability where maliciously crafted names could execute arbitrary SQL during the restore process.
- Fixed a heap buffer overflow vulnerability in libpq for CVE-2025-12818 by hardening memory allocation against integer overflows. This change implements stricter `size_t` calculations for large, untrusted inputs to ensure allocated buffers are sufficient for their contents.

WarehousePG 7.3.1-WHPG

Released: 30 January 2026

WarehousePG 7.3.1-WHPG includes the following new features, enhancements, bug fixes, and other changes:

Enhancements

- Allowed parallel workers to retrieve combo command ids and distributed snapshots directly from Dynamic Shared Memory (DSM).
- Implemented pipes instead of sockets to terminate `poll()` blocking immediately for faster process signaling.
- Added native support for executing `customscans` within the engine.
- Made the `rescanforeignscan` callback optional for foreign data wrappers to improve FDW compatibility.
- Configured GDD to push transaction ids into waitgxids so the query dispatcher can wait on them effectively.
- Appended the WarehousePG name to the end of the version string for better identification.
- Replaced `spinlocks` with `lwlocks` at the instrumentation header to reduce CPU contention.
- Implemented pipes instead of sockets to terminate `poll()` blocking immediately for faster process signaling.
- Updated the build instructions for RHEL8 and RHEL9 systems.
- Updated regression test outputs to reflect recent FDW rescan changes.

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Bug fixes

- Fixed a critical issue with shared snapshots in DSM to prevent potential data loss.
- Resolved a crash in ORCA when processing percentile aggregates.
- Fixed a crash and incorrect results when using distinct qualified aggregates (DQA) with a filter clause.
- Initialized missing `plannedstmt` fields in ORCA to prevent execution errors.
- Corrected the handling of required but unused columns during DXL translation.
- Fixed an incorrect join type assignment when pulling up expression sub-links.
- Adjusted the severity level to warning in `ftsprobe.c` under specific conditions to reduce log noise.
- Removed the `guc_no_show_all` flag for the `archive_timeout` setting.
- Fixed an invalid escape sequence in the `recoveryinfo.py` script.
- Resolved an intermittent failure case in the `pg_waldump` tests.
- Corrected the return type of `gddctxgetmaxvid()` to use `DistributedTransactionId(uint64)`.
- Removed the deprecated `pkg_resources` dependency from the Python environment.

WarehousePG 7.3.0-WHPG

Released: 14 November 2025

WarehousePG 7.3.0-WHPG includes the following new features, enhancements, bug fixes, and other changes:

Enhancements

- Enabled parallel workers context for index builds to improve creation speed.
- Merged Postgres 12 `llvm` changes and implemented explicit `llvmcontextref` for JIT inlining.
- Configured the system to insert WAL records uncompressed if compression fails, ensuring write continuity.
- Updated the copy utility to print the specific `errno` for program pipes.
- Prevented the sorting of in-memory tuples when a process has already been interrupted.
- Enabled builds for the `intarray` and `unaccent` extensions.
- Updated `waitgxids` to use `int64` for better handling of transaction ids.
- Added support for PL/Python2 testing.
- Improved the reliability of error detection in status_check cases.
- Updated the PR template and `.editorconfig` settings.

Bug fixes

- **High availability:** Fixed mirror promotion failures related to WAL segment renaming.
- Resolved a `VACUUM` issue on `AOCS` tables following an aborted `ADD COLUMN` transaction.
- Corrected `pg_exttable` view outputs specifically for ARM systems.
- Implemented recursive calls in the plan walker for `MergeAppend` to ensure plan integrity.
- Fixed a logic error involving `SubPlan PlaceHolderVar`.
- Removed extra blank lines in `EXPLAIN` output.
- Silenced harmless `fsync` errors when parent directories are removed.
- Fixed a `NULL` pointer error during `COPY (SELECT) TO` option validation.
- Dispatched ICU collation comments correctly.
- Stopped reporting `compresstype`, `zlib`, or `zstd` errors when not in the validation phase.
- Fixed inconsistent test cases for `REINDEX TABLE`, `REINDEX INDEX`, and `EXPLAIN FORMAT`.
- Fixed the `gpcheckcat mix_distribution_policy` test.
- Replaced the deprecated Python pipes module.
- Removed `gsutil` from developer requirements.

Security

- Included a fix for CVE-2025-1094.

WarehousePG 7.2.2-WHPG

Released: 17 November 2025

WarehousePG 7.2.2-WHPG includes the following new features, enhancements, bug fixes, and other changes:

Enhancements

- Enabled parallel workers context for index builds to reduce execution time.
- Optimized resource usage by skipping the sorting of in-memory tuples when a process is interrupted.
- Configured WAL records to be inserted uncompressed as a fallback if compression fails.
- Enhanced diagnostic output by printing the specific `errno` for copy program pipes.
- Improved concurrency handling by using `int64` for `waitgxids`.
- Enabled the `unaccent` extension by default.
- Added PL/Python2 testing support for WarehousePG 7 environments.
- Improved the reliability of error detection for `status_check` operations.

Bug fixes

- Fixed a failure in mirror promotion caused by WAL segment renaming.
- Resolved a vacuuming issue on `AOCS` tables that occurred after aborted add column transactions.
- Corrected `pg_exttable` view data for ARM-based architectures.
- Implemented recursive calls in the plan walker for `mergeappend` to ensure correct plan traversal.
- Fixed a sub-plan bug related to placeholder variables.
- Suppressed unnecessary blank lines in `EXPLAIN` output.
- Prevented harmless `fsync` errors from being reported when parent directories are missing.

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- Ensured ICU collation comments are dispatched correctly to maintain metadata.
- Stopped reporting `compresstype` errors during the non-validation phase.
- Silenced `zlib` and `zstd` `reloption` errors during the non-validation phase.
- Reverted the fault tolerance service (FTS) enablement for mirror-less clusters.
- Resolved intermittent test failures in `REINDEX TABLE` and `REINDEX INDEX` cases.
- Fixed an intermittent failure in the `explain_format` test case.
- Fixed the `gpcheckcat` `mix_distribution_policy` test.
- Removed the `gsutil` dependency from development requirements.

Security

- Included a fix for CVE-2025-1094.

WarehousePG 7.2.1-WHPG

Released: 15 May 2025 WarehousePG 7.2.1-WHPG includes the following new features, enhancements, bug fixes, and other changes:

Enhancements

- Fixed a `work_mem` reference in hash aggregates to ensure planned memory is fully utilized and reduce unnecessary disk spills.

Bug fixes

- Resolved a `gpstart` failure caused by a `double free or corruption` error when using OpenSSL 3.2.2.
- Fixed a bug in the Postgres planner where correlated subqueries returned incorrect results due to improper `placeholdervar` handling.
- Resolved an `unexpected gang size` error occasionally encountered in the Postgres planner.
- Initialized `attnumswithentries` to prevent failures during concurrent-only (CO) table rewrites.

Security

- Included a fix for CVE-2023-5869.
- Included a fix for CVE-2024-7348.
- Included a fix for CVE-2024-10979.
- Included a fix for CVE-2024-10976.
- Included a fix for CVE-2022-41862.
- Included a fix for CVE-2023-39417.
- Included a fix for CVE-2024-10978.
- Included a fix for CVE-2024-0978.
- Included a fix for CVE-2024-10977.
- Included a fix for CVE-2023-5870.
- Included a fix for CVE-2023-5868.
- Included a fix for CVE-2024-0985.

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3 Installing and upgrading WarehousePG

Information about installing, configuring, and upgrading WarehousePG software and configuring WarehousePG host machines.

- Platform Requirements
  This topic describes the WarehousePG 7 platform and operating system software requirements.
- Estimating Storage Capacity
  To estimate how much data your WarehousePG cluster can accommodate, use these measurements as guidelines. Also keep in mind that you may want to have extra space for landing backup files and data load files on each segment host.
- Configure Operating System
  Describes how to prepare your operating system environment for WarehousePG software installation.
- Installing WarehousePG
  Describes how to install the WarehousePG software binaries on all of the hosts that will comprise your WarehousePG cluster, how to enable passwordless SSH for the `gpadmin` user, and how to verify the installation.
- Creating the Data Storage Areas
  Describes how to create the directory locations where WarehousePG data is stored for each coordinator, standby, and segment instance.
- Validating the WHPG Cluster
  Validate your hardware and network performance.
- Initializing WarehousePG
  Describes how to initialize a WarehousePG database system.
- Installing Optional Extensions
  Information about installing optional WarehousePG extensions and packages, such as the Procedural Language extensions and the Python and R Data Science Packages.
- Installing Extensions
  The WarehousePG distribution includes several PostgreSQL- and WarehousePG-sourced `contrib` modules that you have the option to install.
- Configuring Timezone and Localization Settings
  Describes the available timezone and localization features of WarehousePG.
- Important Changes Between WHPG 6 and WHPG 7 Describes the changes between WarehousePG 6 and WarehousePG 7 that could potentially affect your existing 6 application when you move to 7.
- Performing a minor upgrade
  Explains how to upgrade to a newer version of WarehousePG 7.x.
- Upgrading from whpg 6 to whpg 7
  Explains how to upgrade from WarehousePG 6 to WarehousePG 7.
- Migrating Partition Maintenance Scripts to the New WarehousePG 7 Partitioning Catalogs Provides guidance on migrating partition maintenance scripts that you may have written for WarehousePG 6 to use the new partitioning system catalogs in WarehousePG 7.
- Enabling iptables (Optional)
  On Linux systems, you can configure and enable the `iptables` firewall to work with WarehousePG.
- Installation Utilities Reference
  References for the command-line management utilities used to install and initialize a WarehousePG cluster.
- WarehousePG Environment Variables
  Reference of the environment variables to set for WarehousePG.
- Example Ansible Playbook A sample Ansible playbook to install a Greenplum Database software release onto the hosts that will comprise a Greenplum Database system.

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3.1 Platform Requirements

This topic describes the WarehousePG 7 platform and operating system software requirements for deploying the software to on-premise hardware, or to public cloud services such as AWS, GCP, or Azure.

Operating System Requirements

WarehousePG 7 runs on the following operating system platforms:

- Red Hat Enterprise Linux 64-bit 8.7 or later
- Oracle Linux 64-bit 8.7 or later, using the Red Hat Compatible Kernel (RHCK)
- Rocky Linux 8.7 or later

> **Note** If you use endpoint security software on your WarehousePG hosts, it may affect your database performance and stability. See About Endpoint Security Sofware for more information.

> **Caution** A kernel issue in Red Hat Enterprise Linux 8.5 and 8.6 can cause I/O freezes and synchronization problems with XFS filesystems. This issue is fixed in RHEL 8.7. See RHEL8: xfs_buf deadlock between inode deletion and block allocation.

WarehousePG server supports TLS version 1.2 on RHEL/CentOS systems, and TLS version 1.3 on Ubuntu systems.

Software Dependencies

WarehousePG 7 requires the following software packages on RHEL systems. The packages are installed automatically as dependencies when you install the WarehousePG RPM package):

- apr
- apr-util
- bash
- bzip2
- curl
- iproute
- krb5-devel
- libcgroup-tools
- libcurl
- libevent
- libuuid
- libuv
- libxml2
- libyaml
- libzstd
- openldap
- openssh
- openssh-client
- openssh-server
- openssl
- openssl-libs
- perl
- python3
- python3-psycopg2
- python3-psutil
- python3-pyyaml
- python3.11
- python3.11-devel
- readline
- rsync
- sed
- tar
- which
- zip
- zlib

WarehousePG 7 client software requires these operating system packages:

- apr
- bzip2
- libedit
- libyaml
- libevent
- libzstd
- openssh
- python3
- python3-psycopg2
- python3-psutil
- python3-pyyaml
- zlib

> **Important** SSL is supported only on the WarehousePG coordinator host system. It cannot be used on the segment host systems.

> **Important** For all WarehousePG host systems, if SELinux is enabled in `Enforcing` mode then the WarehousePG process and users can operate successfully in the default `Unconfined` context. If increased confinement is required, then you must configure SELinux contexts, policies, and domains based on your security requirements, and test your configuration to ensure there is no functionality or performance impact to WarehousePG. Similarly, you should either deactivate or configure firewall software as needed to allow communication between WarehousePG hosts. See Deactivate or Configure SELinux.

Java

WarehousePGd 7 supports these Java versions for PL/Java and PXF:

- Open JDK 8 or Open JDK 11, available from AdoptOpenJDK
- Oracle JDK 8 or Oracle JDK 11

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Python

WarehousePG uses the system default `python3` for the WarehousePG management utilities, and `python3.11` for the PL/Python module. For most of the supported OS versions, the system default `python3` is `python3.9`. If you are installing WarehousePG on Rocky Linux 8, the default `python3` version included is `python3.6`. You may want to unify the `python3` versions to `python3.11` by running the following commands:

```
sudo yum install python3.11 python3.11-devel python3.11-psycopg2 python3.11-pyyaml python3.11-psutil
sudo update-alternatives set python3 /usr/bin/python3.11
sudo update-alternatives set python /usr/bin/python3.11
```

WarehousePG Tools and Extensions Compatibility

Client Tools

The WarehousePG 7 Clients tool package is supported on the following platforms:

- Red Hat Enterprise Linux x86_64 8.x (RHEL 8)
- Oracle Linux 64-bit 8, using the Red Hat Compatible Kernel (RHCK)
- Rocky Linux 8
- Windows 10 (64-bit)
- Windows 8 (64-bit)
- Windows Server 2012 (64-bit)
- Windows Server 2012 R2 (64-bit)
- Windows Server 2008 R2 (64-bit)

The WarehousePG 7 Clients package includes the client and loader programs plus database/role/language commands. Refer to WarehousePG Client and Loader Tools Package for installation and usage details of the WarehousePG 7 Client tools.

Extensions

This table lists the versions of the WarehousePG Extensions that are compatible with this release of WarehousePG 7.

WarehousePG Extensions Compatibility

Component	Package Version	Additional Information
PL/Java	2.0.7	Supports Java 8 and 11.
Python 3.11 Data Science Module Package	1.2	
PL/R	3.1.1	(CentOS) R 3.3.3 (Ubuntu) You install R 3.5.1+.
R Data Science Library Package	2.0.2	
PL/Container Image for R	2.1.2	R 3.6.3
PL/Container Images for Python	2.1.2	Python 2.7.12 Python 3.7
MADlib Machine Learning	2.1.0	Support matrix at MADlib FAQ.
PostGIS Spatial and Geographic Objects	3.3.2	

For information about the Oracle Compatibility Functions, see Oracle Compatibility Functions.

These WarehousePG extensions are installed with WarehousePG

- Fuzzy String Match Extension
- PL/Python Extension
- pgcrypto Extension

Hardware Requirements

The following table lists minimum recommended specifications for hardware servers intended to support WarehousePG on Linux systems in a production environment. All host servers in your WarehousePG cluster must have the same hardware and software configuration. WarehousePG also provides hardware build guides for its certified hardware platforms. Work with a WarehousePG clusters Engineer to review your anticipated environment to ensure an appropriate hardware configuration for WarehousePG.

Minimum Hardware Requirements

Minimum CPU	Any x86_64 compatible CPU
Minimum Memory	16 GB RAM per server
Disk Space Requirements	• 150MB per host for WarehousePG installation • Approximately 300MB per segment instance for metadata • Cap disk capacity at 70% full to accommodate temporary files and prevent performance degradation

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Network Requirements	10 Gigabit Ethernet within the array NIC bonding is recommended when multiple interfaces are present WarehousePG can use either IPV4 or IPV6 protocols.

Hyperthreading

Resource Groups - one of the key WarehousePG features - can control transaction concurrency, CPU and memory resources, workload isolation, and dynamic bursting.

When using resource groups to control resource allocation on Intel based systems, consider switching off Hyper-Threading (HT) in the server BIOS (for Intel cores the default is ON). Switching off HT might cause a small throughput reduction (less than 15%), but can achieve greater isolation between resource groups, and higher query performance with lower concurrency workloads.

Storage

The only file system supported for running WarehousePG is the XFS file system. All other file systems are explicitly *not* supported by WarehousePG.

WarehousePG is supported on network or shared storage if the shared storage is presented as a block device to the servers running WarehousePG and the XFS file system is mounted on the block device. Network file systems are*not* supported. When using network or shared storage, WarehousePG mirroring must be used in the same way as with local storage, and no modifications may be made to the mirroring scheme or the recovery scheme of the segments.

Other features of the shared storage such as de-duplication and/or replication are not directly supported by WarehousePG, but may be used with support of the storage vendor as long as they do not interfere with the expected operation of WarehousePG.

WarehousePG can be deployed to virtualized systems only if the storage is presented as block devices and the XFS file system is mounted for the storage of the segment directories.

WarehousePG is supported on Amazon Web Services (AWS) servers using either Amazon instance store (Amazon uses the volume names `ephemeral[0-23]`) or Amazon Elastic Block Store (Amazon EBS) storage. If using Amazon EBS storage the storage should be RAID of Amazon EBS volumes and mounted with the XFS file system for it to be a supported configuration.

Hadoop Distributions

WarehousePG provides access to HDFS with the WarehousePG Platform Extension Framework PXF

PXF can use Cloudera and generic Apache Hadoop distributions. PXF bundles all of the JAR files on which it depends, including the following Hadoop libraries:

PXF Version	Hadoop Version	Hive Server Version	HBase Server Version
6.x, 5.15.x, 5.14.0, 5.13.0, 5.12.0, 5.11.1, 5.10.1	2.x, 3.1+	1.x, 2.x, 3.1+	1.3.2
5.8.2	2.x	1.x	1.3.2
5.8.1	2.x	1.x	1.3.2

> **Note** If you plan to access JSON format data stored in a Cloudera Hadoop cluster, PXF requires a Cloudera version 5.8 or later Hadoop distribution.

Public Cloud Requirements

Operating System

The operating system parameters for cloud deployments are the same as on-premise with a few modifications. Use the WarehousePG Installation Guide for reference. Additional changes are as follows:

Add the following line to `sysctl.conf`:

```
net.ipv4.ip_local_reserved_ports=65330
```

AWS requires loading network drivers and also altering the Amazon Machine Image (AMI) to use the faster networking capabilities. More information on this is provided in the AWS documentation.

Storage

The disk settings for cloud deployments are the same as on-premise with a few modifications. Use the WarehousePG Installation Guide for reference. Additional changes are as follows:

- Mount options:

  ```
  rw,noatime,nobarrier,nodev,inode64
  ```

  > **Note** The `nobarrier` option is not supported on RHEL 8 or Ubuntu nodes.

- Use mq-deadline instead of the deadline scheduler for the R5 series instance type in AWS
- Use a swap disk per VM (32GB size works well)

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Amazon Web Services (AWS)

Virtual Machine Type

AWS provides a wide variety of virtual machine types and sizes to address virtually every use case. Testing in AWS has found that the optimal instance types for WarehousePG are "Memory Optimized". These provide the ideal balance of Price, Memory, Network, and Storage throughput, and Compute capabilities.

Price, Memory, and number of cores typically increase in a linear fashion, but the network speed and disk throughput limits do not. You may be tempted to use the largest instance type to get the highest network and disk speed possible per VM, but better overall performance for the same spend on compute resources can be obtained by using more VMs that are smaller in size.

Compute

AWS uses Hyperthreading when reporting the number of vCPUs, therefore 2 vCPUs equates to 1 Core. The processor types are frequently getting faster so using the latest instance type will be not only faster, but usually less expensive. For example, the R5 series provides faster cores at a lower cost compared to R4.

Memory

This variable is pretty simple. WarehousePG needs at least 8GB of RAM per segment process to work optimally. More RAM per segment helps with concurrency and also helps hide disk performance deficiencies.

Network

AWS provides 25Gbit network performance on the largest instance types, but the network is typically not the bottleneck in AWS. The "up to 10Gbit" network is sufficient in AWS.

Installing network drivers in the VM is also required in AWS, and depends on the instance type. Some instance types use an Intel driver while others use an Amazon ENA driver. Loading the driver requires modifying the machine image (AMI) to take advantage of the driver.

Storage

Elastic Block Storage (EBS)

The AWS default disk type is General Performance (GP2) which is ideal for IOP dependent applications. GP2 uses SSD disks and relative to other disk types in AWS, is expensive. The operating system and swap volumes are ideal for GP2 disks because of the size and higher random I/O needs.

Throughput Optimized Disks (ST1) are a disk type designed for high throughput needs such as WarehousePG. These disks are based on HDD rather than SSD, and are less expensive than GP2. Use this disk type for the optimal performance of loading and SQL: Querying Data in AWS.

Cold Storage (SC1) provides the best value for EBS storage in AWS. Using multiple 2TB or larger disks provides enough disk throughput to reach the throughput limit of many different instance types. Therefore, it is possible to reach the throughput limit of a VM by using SC1 disks.

EBS storage is durable so data is not lost when a virtual machine is stopped. EBS also provides infrastructure snapshot capabilities that can be used to create volume backups. These snapshots can be copied to different regions to provide a disaster recovery solution. The WarehousePG Cloud utility `gpsnap`, available in the AWS Cloud Marketplace, automates backup, restore, delete, and copy functions using EBS snapshots.

Storage can be grown in AWS with "gpgrow". This tool is included with the WarehousePG on AWS deployment and allows you to grow the storage independently of compute. This is an online operation in AWS too.

Ephemeral

Ephemeral Storage is directly attached to VMs, but has many drawbacks:

- Data loss when stopping a VM with ephemeral storage
- Encryption is not supported
- No Snapshots
- Same speed can be achieved with EBS storage
- Not recommended

AWS Recommendations

####### Coordinator

Instance Type	Memory	vCPUs	Data Disks
r5.xlarge	32	4	1
r5.2xlarge	64	8	1
r5.4xlarge	128	16	1

####### Segments

Instance Type	Memory	vCPUs	Data Disks
r5.4xlarge	128	16	3

Performance testing has indicated that the Coordinator node can be deployed on the smallest r5.xlarge instance type to save money without a measurable difference in performance. Testing was performed using the TPC-DS benchmark.

The Segment instances run optimally on the r5.4xlarge instance type. This provides the highest performance given the cost of the AWS resources.

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Google Compute Platform (GCP)

Virtual Machine Type

The two most common instance types in GCP are "Standard" or "HighMem" instance types. The only difference is the ratio of Memory to Cores. Each offer 1 to 64 vCPUs per VM.

Compute

Like AWS, GCP uses Hyperthreading, so 2 vCPUs equates to 1 Core. The CPU clock speed is determined by the region in which you deploy.

Memory

Instance type n1-standard-8 has 8 vCPUs with 30GB of RAM while n1-highmem-8 also has 8 vCPUs with 52GB of RAM. There is also a HighCPU instance type that generally isn't ideal for WarehousePG. Like AWS and Azure, the machines with more vCPUs will have more RAM.

Network

GCP network speeds are dependent on the instance type but the maximum network performance is possible (10Gbit) with a virtual machine as small as only 8 vCPUs.

Storage

Standard (HDD) and SSD disks are available in GCP. SSD is slightly faster in terms of throughput but comes at a premium. The size of the disk does not impact performance.

The biggest obstacle to maximizing storage performance is the throughput limit placed on every virtual machine. Unlike AWS and Azure, the storage throughput limit is relatively low, consistent across all instance types, and only a single disk is needed to reach the VM limit.

GCP Recommendations

Testing has revealed that *while using the same number of vCPUs*, a cluster using a large instance type like n1-highmem-64 (64 vCPUs) will have lower performance than a cluster using more of the smaller instance types like n1-highmem-8 (8 vCPUs). In general, use 8x more nodes in GCP than you would in another environment like AWS while using the 8 vCPU instance types.

The HighMem instance type is slightly faster for higher concurrency. Furthermore, SSD disks are slightly faster also but come at a cost.

####### Coordinator and Segment Instances

Instance Type	Memory	vCPUs	Data Disks
n1-standard-8	30	8	1
n1-highmem-8	52	8	1

Azure

> **Note** On the Azure platform, in addition to bandwidth, the number of network connections present on a VM at any given moment can affect the VM's network performance. The Azure networking stack maintains the state for each direction of a TCP/UDP connection in a data structures called a *flow*. A typical TCP/UDP connection will have 2 flows created: one for the inbound direction and another for the outbound direction. The number of network flows on Azure is limited to an upper bound. See Virtual machine network bandwidth in the Azure documentation for more details. In practice this can present scalability challenges for workloads based on the number of concurrent queries, and on the complexity of those queries. Always test your workload on Azure to validate that you are within the Azure limits, and be advised that if your workload increases you may hit Azure flow count boundaries at which point your workload may fail. It is recomended to use the UDP interconnect, and not the TCP interconnect, when using Azure. A connection pooler and resource group settings can also be used to help keep flow counts at a lower level.

Virtual Machine Type

Each VM type has limits on disk throughput so picking a VM that doesn't have a limit that is too low is essential. Most of Azure is designed for OLTP or Application workloads, which limits the choices for databases like WarehousePG where throughput is more important. Disk type also plays a part in the throughput cap, so that needs to be considered too.

Compute

Most instance types in Azure have hyperthreading enabled, which means 1 vCPU equates to 2 cores. However, not all instance types have this feature, so for these others, 1 vCPU equates to 1 core.

The High Performance Compute (HPC) instance types have the fastest cores in Azure.

Memory

In general, the larger the virtual machine type, the more memory the VM will have.

Network

The Accelerated Networking option offloads CPU cycles for networking to "FPGA-based SmartNICs". Virtual machine types either support this or do not, but most do support it. Testing of WarehousePG hasn't shown much difference and this is probably because of Azure's preference for TCP over UDP. Despite this, UDPIFC interconnect is the ideal protocol to use in Azure.

There is an undocumented process in Azure that periodically runs on the host machines on UDP port 65330. When a query runs using UDP port 65330 and this undocumented process runs, the query will fail after one hour with an interconnect timeout error. This is fixed by reserving port 65330 so that WarehousePG doesn't use it.

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Storage

Storage in Azure is either Premium (SSD) or Regular Storage (HDD). The available sizes are the same and max out at 4TB. Instance types either do or do not support Premium but, interestingly, the instance types that do support Premium storage, have a *lower* throughput limit. For example:

- Standard_E32s_v3 has a limit of 768 MB/s.
- Standard_E32_v3 was tested with `gpcheckperf` to have 1424 write and 1557 read MB/s performance.

To get the maximum throughput from a VM in Azure, you have to use multiple disks. For larger instance types, you have to use upwards of 32 disks to reach the limit of a VM. Unfortunately, the memory and CPU constraints on these machines means that you have to run fewer segments than you have disks, so you have to use software RAID to utilize all of these disks. Performance takes a hit with software RAID, too, so you have to try multiple configurations to optimize.

The size of the disk also impacts performance, but not by much.

Software RAID not only is a little bit slower, but it also requires `umount` to take a snapshot. This greatly lengthens the time it takes to take a snapshot backup.

Disks use the same network as the VMs so you start running into the Azure limits in bigger clusters when using big virtual machines with 32 disks on each one. The overall throughput drops as you hit this limit and is most noticeable during concurrency testing.

Azure Recommendations

The best instance type to use in Azure is "Standard_H8" which is one of the High Performance Compute instance types. This instance series is the only one utilizing InfiniBand, but this does not include IP traffic. Because this instance type is n0t available in all regions, the "Standard_D13_v2" is also available.

####### Coordinator

Instance Type	Memory	vCPUs	Data Disks
D13_v2	56	8	1
H8	56	8	1

####### Segments

Instance Type	Memory	vCPUs	Data Disks
D13_v2	56	8	2
H8	56	8	2

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3.2 Estimating Storage Capacity

To estimate how much data your WarehousePG cluster can accommodate, use these measurements as guidelines. Also keep in mind that you may want to have extra space for landing backup files and data load files on each segment host.

- Calculating Usable Disk Capacity
- Calculating User Data Size
- Calculating Space Requirements for Metadata and Logs

Parent topic: Installing and Upgrading WarehousePG

Calculating Usable Disk Capacity

To calculate how much data a WarehousePG cluster can hold, you have to calculate the usable disk capacity per segment host and then multiply that by the number of segment hosts in your WarehousePG cluster. Start with the raw capacity of the physical disks on a segment host that are available for data storage (raw_capacity), which is:

```
disk_size * number_of_disks
```

Account for file system formatting overhead (roughly 10 percent) and the RAID level you are using. For example, if using RAID-10, the calculation would be:

```
(raw_capacity * 0.9) / 2 = formatted_disk_space
```

For optimal performance, do not completely fill your disks to capacity, but run at 70% or lower. So with this in mind, calculate the usable disk space as follows:

```
formatted_disk_space * 0.7 = usable_disk_space
```

Using only 70% of your disk space allows WarehousePG to use the other 30% for temporary and transaction files on the same disks. If your host systems have a separate disk system that can be used for temporary and transaction files, you can specify a tablespace that WarehousePG uses for the files. Moving the location of the files might improve performance depending on the performance of the disk system.

Once you have formatted RAID disk arrays and accounted for the maximum recommended capacity (usable_disk_space), you will need to calculate how much storage is actually available for user data (`U`). If using WarehousePG mirrors for data redundancy, this would then double the size of your user data (`2 * U`). WarehousePG also requires some space be reserved as a working area for active queries. The work space should be approximately one third the size of your user data (work space = `U/3`):

```
With mirrors: (2 * U) + U/3 = usable_disk_space

Without mirrors: U + U/3 = usable_disk_space
```

Guidelines for temporary file space and user data space assume a typical analytic workload. Highly concurrent workloads or workloads with queries that require very large amounts of temporary space can benefit from reserving a larger working area. Typically, overall system throughput can be increased while decreasing work area usage through proper workload management. Additionally, temporary space and user space can be isolated from each other by specifying that they reside on different tablespaces.

In the *WarehousePG Administrator Guide*, see these topics:

- Managing Performance for information about workload management
- Creating and Managing Tablespaces for information about moving the location of temporary and transaction files
- Monitoring System State for information about monitoring WarehousePG disk space usage

Parent topic: Estimating Storage Capacity

Calculating User Data Size

As with all databases, the size of your raw data will be slightly larger once it is loaded into the database. On average, raw data will be about 1.4 times larger on disk after it is loaded into the database, but could be smaller or larger depending on the data types you are using, table storage type, in-database compression, and so on.

- Page Overhead - When your data is loaded into WarehousePG, it is divided into pages of 32KB each. Each page has 20 bytes of page overhead.
- Row Overhead - In a regular 'heap' storage table, each row of data has 24 bytes of row overhead. An 'append-optimized' storage table has only 4 bytes of row overhead.
- Attribute Overhead - For the data values itself, the size associated with each attribute value is dependent upon the data type chosen. As a general rule, you want to use the smallest data type possible to store your data (assuming you know the possible values a column will have).
- Indexes - In WarehousePG, indexes are distributed across the segment hosts as is table data. The default index type in WarehousePG is B-tree. Because index size depends on the number of unique values in the index and the data to be inserted, precalculating the exact size of an index is impossible. However, you can roughly estimate the size of an index using these formulas.

  ```
  B-tree: unique_values * (data_type_size + 24 bytes)

  Bitmap: (unique_values * =number_of_rows * 1 bit * compression_ratio / 8) + (unique_values * 32)
  ```

Parent topic: Estimating Storage Capacity

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Calculating Space Requirements for Metadata and Logs

On each segment host, you will also want to account for space for WarehousePG log files and metadata:

- **System Metadata** — For each WarehousePG segment instance (primary or mirror) or coordinator instance running on a host, estimate approximately 20 MB for the system catalogs and metadata.
- **Write Ahead Log** — For each WarehousePG segment (primary or mirror) or coordinator instance running on a host, allocate space for the write ahead log (WAL). The WAL is divided into segment files of 64 MB each. At most, the maximum number of WAL files will be:

  ```
  max_wal_size / 64MB
  ```

  You can use this to estimate space requirements for WAL. The default checkpoint_segments setting for a WarehousePG instance is 8, meaning 1088 MB WAL space allocated for each segment or coordinator instance on a host.
- **WarehousePG Log Files** — Each segment instance and the coordinator instance generates database log files, which will grow over time. Sufficient space should be allocated for these log files, and some type of log rotation facility should be used to ensure that to log files do not grow too large.

Parent topic: Estimating Storage Capacity

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3.3 Configure Operating System

Describes how to prepare your operating system environment for WarehousePG software installation.

Perform the following tasks in order:

1. Make sure your host systems meet the requirements described in On-Premise Hardware Requirements.
2. Deactivate or configure SELinux.
3. Deactivate or configure firewall software.
4. Set the required operating system parameters.
5. Synchronize system clocks.
6. Create the gpadmin account.

Unless noted, these tasks should be performed for *all* hosts in your WarehousePG cluster (coordinator, standby coordinator, and segment hosts).

The WarehousePG host naming convention for the coordinator host is `cdw` and for the standby coordinator host is `scdw`.

The segment host naming convention is sdwN where sdw is a prefix and N is an integer. For example, segment host names would be `sdw1`, `sdw2` and so on. NIC bonding is recommended for hosts with multiple interfaces, but when the interfaces are not bonded, the convention is to append a dash (`-`) and number to the host name. For example, `sdw1-1` and `sdw1-2` are the two interface names for host `sdw1`.

> **Important** When data loss is not acceptable for a WarehousePG cluster, WarehousePG coordinator and segment mirroring is recommended. If mirroring is not enabled then WarehousePG stores only one copy of the data, so the underlying storage media provides the only guarantee for data availability and correctness in the event of a hardware failure.

> **Note** For information about upgrading WarehousePG from a previous version, see the *WarehousePG Release Notes* for the release that you are installing.

> **Note** Automating the configuration steps described in this topic and Installing WarehousePG with a system provisioning tool, such as Ansible, Chef, or Puppet, can save time and ensure a reliable and repeatable WarehousePG installation.

Parent topic: Installing and Upgrading WarehousePG

Deactivate or Configure SELinux

For all WarehousePG host systems running RHEL/Oracle/Rocky Linux, SELinux must either be `Disabled` or configured to allow unconfined access to WarehousePG processes, directories, and the gpadmin user.

If you choose to deactivate SELinux:

1. As the root user, check the status of SELinux:

   ```
   # sestatus
   SELinuxstatus: disabled
   ```

2. If SELinux is not deactivated, deactivate it by editing the `/etc/selinux/config` file. As root, change the value of the `SELINUX` parameter in the `config` file as follows:

   ```
   SELINUX=disabled
   ```

3. If the System Security Services Daemon (SSSD) is installed on your systems, edit the SSSD configuration file and set the `selinux_provider` parameter to `none` to prevent SELinux-related SSH authentication denials that could occur even with SELinux deactivated. As root, edit `/etc/sssd/sssd.conf` and add this parameter:

   ```
   selinux_provider=none
   ```

4. Reboot the system to apply any changes that you made and verify that SELinux is deactivated.

If you choose to enable SELinux in `Enforcing` mode, then WarehousePG processes and users can operate successfully in the default `Unconfined` context. If you require increased SELinux confinement for WarehousePG processes and users, you must test your configuration to ensure that there are no functionality or performance impacts to WarehousePG. See the SELinux User's and Administrator's Guide for detailed information about configuring SELinux and SELinux users.

Deactivate or Configure Firewall Software

You should also deactivate firewall software such as `firewalld` (on systems such as RHEL). If firewall software is not deactivated, you must instead configure your software to allow required communication between WarehousePG hosts.

1. Check the status of `firewalld` with the command:

   ```
   # systemctl status firewalld
   ```

   If `firewalld` is deactivated, the command output is:

   ```
   * firewalld.service - firewalld - dynamic firewall daemon
      Loaded: loaded (/usr/lib/systemd/system/firewalld.service; disabled; vendor preset: enabled)
      Active: inactive (dead)
   ```

2. If necessary, run these commands as root to deactivate `firewalld`:

   ```
   # systemctl stop firewalld.service
   # systemctl disable firewalld.service
   ```

See the documentation for the firewall or your operating system for additional information.

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Recommended OS Parameters Settings

WarehousePG requires that certain Linux operating system (OS) parameters be set on all hosts in your WarehousePG cluster (coordinators and segments).

In general, the following categories of system parameters need to be altered:

- **Shared Memory** - A WarehousePG instance will not work unless the shared memory segment for your kernel is properly sized. Most default OS installations have the shared memory values set too low for WarehousePG. On Linux systems, you must also deactivate the OOM (out of memory) killer. For information about WarehousePG shared memory requirements, see the WarehousePG server configuration parameter shared_buffers in the *WarehousePG Reference Guide*.
- **Network** - On high-volume WarehousePG clusters, certain network-related tuning parameters must be set to optimize network connections made by the WarehousePG interconnect.
- **User Limits** - User limits control the resources available to processes started by a user's shell. WarehousePG requires a higher limit on the allowed number of file descriptors that a single process can have open. The default settings may cause some WarehousePG queries to fail because they will run out of file descriptors needed to process the query.

More specifically, you need to edit the following Linux configuration settings:

- The hosts File
- The sysctl.conf File
- System Resources Limits
- Core Dump
- XFS Mount Options
- Disk I/O Settings
  - Read ahead values
  - Disk I/O scheduler disk access

- Networking
- Transparent Huge Pages (THP)
- IPC Object Removal
- SSH Connection Threshold

The hosts File

Edit the `/etc/hosts` file and make sure that it includes the host names and all interface address names for every machine participating in your WarehousePG cluster.

The sysctl.conf File

The `sysctl.conf` parameters listed in this topic are for performance, optimization, and consistency in a wide variety of environments. Change these settings according to your specific situation and setup.

Set the parameters in the `/etc/sysctl.conf` file and reload with `sysctl -p`:

```
# kernel.shmall = _PHYS_PAGES / 2 # See Shared Memory Pages
kernel.shmall = 197951838
# kernel.shmmax = kernel.shmall * PAGE_SIZE
kernel.shmmax = 810810728448
kernel.shmmni = 4096
vm.overcommit_memory = 2 # See Segment Host Memory
vm.overcommit_ratio = 95 # See Segment Host Memory

net.ipv4.ip_local_port_range = 10000 65535 # See Port Settings
kernel.sem = 250 2048000 200 8192
kernel.sysrq = 1
kernel.core_uses_pid = 1
kernel.msgmnb = 65536
kernel.msgmax = 65536
kernel.msgmni = 2048
net.ipv4.tcp_syncookies = 1
net.ipv4.conf.default.accept_source_route = 0
net.ipv4.tcp_max_syn_backlog = 4096
net.ipv4.conf.all.arp_filter = 1
net.ipv4.ipfrag_high_thresh = 41943040
net.ipv4.ipfrag_low_thresh = 31457280
net.ipv4.ipfrag_time = 60
net.core.netdev_max_backlog = 10000
net.core.rmem_max = 2097152
net.core.wmem_max = 2097152
vm.swappiness = 10
vm.zone_reclaim_mode = 0
vm.dirty_expire_centisecs = 500
vm.dirty_writeback_centisecs = 100
vm.dirty_background_ratio = 0 # See System Memory
vm.dirty_ratio = 0
vm.dirty_background_bytes = 1610612736
vm.dirty_bytes = 4294967296
```

Shared Memory Pages

WarehousePG uses shared memory to communicate between `postgres` processes that are part of the same `postgres` instance. `kernel.shmall` sets the total amount of shared memory, in pages, that can be used system wide. `kernel.shmmax` sets the maximum size of a single shared memory segment in bytes.

Set `kernel.shmall` and `kernel.shmmax` values based on your system's physical memory and page size. In general, the value for both parameters should be one half of the system physical memory.

Use the operating system variables `_PHYS_PAGES` and `PAGE_SIZE` to set the parameters.

```
kernel.shmall = ( _PHYS_PAGES / 2)
kernel.shmmax = ( _PHYS_PAGES / 2) * PAGE_SIZE
```

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To calculate the values for `kernel.shmall` and `kernel.shmmax`, run the following commands using the `getconf` command, which returns the value of an operating system variable.

```
$ echo $(expr $(getconf _PHYS_PAGES) / 2)
$ echo $(expr $(getconf _PHYS_PAGES) / 2 \* $(getconf PAGE_SIZE))
```

As best practice, we recommend you set the following values in the `/etc/sysctl.conf` file using calculated values. For example, a host system has 1583 GB of memory installed and returns these values: _PHYS_PAGES = 395903676 and PAGE_SIZE = 4096. These would be the `kernel.shmall` and `kernel.shmmax` values:

```
kernel.shmall = 197951838
kernel.shmmax = 810810728448
```

If the WarehousePG coordinator has a different shared memory configuration than the segment hosts, the _PHYS_PAGES and PAGE_SIZE values might differ, and the `kernel.shmall` and `kernel.shmmax` values on the coordinator host will differ from those on the segment hosts.

Segment Host Memory

The `vm.overcommit_memory` Linux kernel parameter is used by the OS to determine how much memory can be allocated to processes. For WarehousePG, this parameter should always be set to 2.

`vm.overcommit_ratio` is the percent of RAM that is used for application processes and the remainder is reserved for the operating system. The default is 50 on Red Hat Enterprise Linux.

For `vm.overcommit_ratio` tuning and calculation recommendations with resource group-based resource management or resource queue-based resource management, refer to Options for Configuring Segment Host Memory in the *WarehousePG Administrator Guide*.

Port Settings

To avoid port conflicts between WarehousePG and other applications during WarehousePG initialization, make a note of the port range specified by the operating system parameter `net.ipv4.ip_local_port_range`. When initializing WarehousePG using the `gpinitsystem` cluster configuration file, do not specify WarehousePG ports in that range. For example, if `net.ipv4.ip_local_port_range = 10000 65535`, set the WarehousePG base port numbers to these values.

```
PORT_BASE = 6000
MIRROR_PORT_BASE = 7000
```

For information about the `gpinitsystem` cluster configuration file, see Initializing WarehousePG.

For Azure deployments with WarehousePG avoid using port 65330; add the following line to sysctl.conf:

```
net.ipv4.ip_local_reserved_ports=65330
```

For additional requirements and recommendations for cloud deployments, see Public Cloud Requirements.

IP Fragmentation Settings

When the WarehousePG interconnect uses UDP (the default), the network interface card controls IP packet fragmentation and reassemblies.

If the UDP message size is larger than the size of the maximum transmission unit (MTU) of a network, the IP layer fragments the message. (Refer to Networking later in this topic for more information about MTU sizes for WarehousePG.) The receiver must store the fragments in a buffer before it can reorganize and reassemble the message.

The following `sysctl.conf` operating system parameters control the reassembly process:

OS Parameter	Description
net.ipv4.ipfrag_high_thresh	The maximum amount of memory used to reassemble IP fragments before the kernel starts to remove fragments to free up resources. The default value is 4194304 bytes (4MB).
net.ipv4.ipfrag_low_thresh	The minimum amount of memory used to reassemble IP fragments. The default value is 3145728 bytes (3MB). (Deprecated after kernel version 4.17.)
net.ipv4.ipfrag_time	The maximum amount of time (in seconds) to keep an IP fragment in memory. The default value is 30.

The recommended settings for these parameters for WarehousePG follow:

```
net.ipv4.ipfrag_high_thresh = 41943040
net.ipv4.ipfrag_low_thresh = 31457280
net.ipv4.ipfrag_time = 60
```

System Memory

For host systems with more than 64GB of memory, these settings are recommended:

```
vm.dirty_background_ratio = 0
vm.dirty_ratio = 0
vm.dirty_background_bytes = 1610612736 # 1.5GB
vm.dirty_bytes = 4294967296 # 4GB
```

For host systems with 64GB of memory or less, remove `vm.dirty_background_bytes` and `vm.dirty_bytes` and set the two `ratio` parameters to these values:

```
vm.dirty_background_ratio = 3
vm.dirty_ratio = 10
```

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Increase `vm.min_free_kbytes` to ensure `PF_MEMALLOC` requests from network and storage drivers are easily satisfied. This is especially critical on systems with large amounts of system memory. The default value is often far too low on these systems. Use this awk command to set `vm.min_free_kbytes` to a recommended 3% of system physical memory:

```
awk 'BEGIN {OFMT = "%.0f";} /MemTotal/ {print "vm.min_free_kbytes =", $2 * .03;}'
             /proc/meminfo >> /etc/sysctl.conf
```

Do not set `vm.min_free_kbytes` to higher than 5% of system memory as doing so might cause out of memory conditions.

System Resources Limits

Set the following parameters in the `/etc/security/limits.conf` file:

```
* soft nofile 524288
* hard nofile 524288
* soft nproc 131072
* hard nproc 131072
```

For Red Hat Enterprise Linux (RHEL) systems, parameter values in the `/etc/security/limits.d/20-nproc.conf` file override the values in the `limits.conf` file. Ensure that any parameters in the override file are set to the required value. The Linux module `pam_limits` sets user limits by reading the values from the `limits.conf` file and then from the override file. For information about PAM and user limits, see the documentation on PAM and `pam_limits`.

Run the `ulimit -u` command on each segment host to display the maximum number of processes that are available to each user. Validate that the return value is `131072`.

Core Dump

Enable core file generation to a known location by adding the following line to `/etc/sysctl.conf`:

```
kernel.core_pattern = /var/crash/core-%e-%s-%u-%g-%p-%t
```

Add the following line to `/etc/security/limits.conf`:

```
* soft  core unlimited
```

To apply the changes to the live kernel, run the following command:

```
# sysctl -p
```

XFS Mount Options

XFS is the preferred data storage file system on Linux platforms. Use the `mount` command with the following recommended XFS mount options for RHEL systems:

```
rw,nodev,noatime,inode64
```

See the `mount` manual page (`man mount` opens the man page) for more information about using this command.

The XFS options can also be set in the `/etc/fstab` file. This example entry from an `fstab` file specifies the XFS options.

```
/dev/data /data xfs nodev,noatime,inode64 0 0
```

> **Note** You must have root permission to edit the `/etc/fstab` file.

Disk I/O Settings

- Read-ahead value

  Each disk device file should have a read-ahead (`blockdev`) value of `16384`. To verify the read-ahead value of a disk device:

  ```
  # sudo /sbin/blockdev --getra <devname>
  ```

  For example:

  ```
  # sudo /sbin/blockdev --getra /dev/sdb
  ```

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To set blockdev (read-ahead) on a device:

```
# sudo /sbin/blockdev --setra <bytes> <devname>
```

For example:

```
# sudo /sbin/blockdev --setra 16384 /dev/sdb
```

See the manual page (man) for the `blockdev` command for more information about using that command (`man blockdev` opens the man page).

> **Note** The `blockdev --setra` command is not persistent. You must ensure the read-ahead value is set whenever the system restarts. How to set the value will vary based on your system.

One method to set the `blockdev` value at system startup is by adding the `/sbin/blockdev --setra` command in the `rc.local` file. For example, add this line to the `rc.local` file to set the read-ahead value for the disk `sdb`.

```
/sbin/blockdev --setra 16384 /dev/sdb
```

On systems that use systemd, you must also set the execute permissions on the `rc.local` file to enable it to run at startup. For example, on a RHEL system, this command sets execute permissions on the file.

```
# chmod +x /etc/rc.d/rc.local
```

Restart the system to have the setting take effect.

- Disk I/O scheduler

  The Linux disk scheduler orders the I/O requests submitted to a storage device, controlling the way the kernel commits reads and writes to disk.

  A typical Linux disk I/O scheduler supports multiple access policies. The optimal policy selection depends on the underlying storage infrastructure. The recommended scheduler policy settings for WarehousePG clusters for specific OSs and storage device types follow:

Storage Device Type	OS	Recommended Scheduler Policy
Non-Volatile Memory Express (NVMe)	RHEL 7 RHEL 8 RHEL 9 Ubuntu	`none`
Solid-State Drives (SSD)	RHEL 7	`noop`
Solid-State Drives (SSD)	RHEL 8 RHEL 9 Ubuntu	`none`
Other	RHEL 7	`deadline`
Other	RHEL 8 RHEL 9 Ubuntu	`mq-deadline`

  To specify a scheduler until the next system reboot, run the following:

```
# echo schedulername > /sys/block/<devname>/queue/scheduler
```

  For example:

```
# echo deadline > /sys/block/sbd/queue/scheduler
```

> **Note** Using the `echo` command to set the disk I/O scheduler policy is not persistent; you must ensure that you run the command whenever the system reboots. How to run the command will vary based on your system.

  To specify the I/O scheduler at boot time on systems that use `grub2`, use the system utility `grubby`. This command adds the parameter when run as `root`:

```
# grubby --update-kernel=ALL --args="elevator=deadline"
```

  After adding the parameter, reboot the system.

  This `grubby` command displays kernel parameter settings:

```
# grubby --info=ALL
```

  Refer to your operating system documentation for more information about the `grubby` utility. If you used the `grubby` command to configure the disk scheduler on a RHEL system and it does not update the kernels, see the Note at the end of the section.

  For additional information about configuring the disk scheduler, refer to the RedHat Enterprise Linux documentation forRHEL 8.

Networking

The maximum transmission unit (MTU) of a network specifies the size (in bytes) of the largest data packet/frame accepted by a network-connected device. A jumbo frame is a frame that contains more than the standard MTU of 1500 bytes.

WarehousePG utilizes 3 distinct MTU settings:

- The WarehousePG gp_max_packet_size server configuration parameter. The default max packet size is 8192. This default assumes a jumbo frame MTU.

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- The operating system MTU setting.
- The rack switch MTU setting.

These settings are connected, in that they should always be either the same, or close to the same, value, or otherwise in the order of WarehousePG < OS < switch for MTU size.

9000 is a common supported setting for switches, and is the recommended OS and rack switch MTU setting for your WarehousePG hosts.

Transparent Huge Pages (THP)

Deactivate Transparent Huge Pages (THP) as it degrades WarehousePG performance. RHEL 6.0 or higher enables THP by default. One way to deactivate THP on RHEL 6.x is by adding the parameter `transparent_hugepage=never` to the kernel command in the file `/boot/grub/grub.conf`, the GRUB boot loader configuration file. This is an example kernel command from a `grub.conf` file. The command is on multiple lines for readability:

```
kernel /vmlinuz-2.6.18-274.3.1.el5 ro root=LABEL=/
          elevator=deadline crashkernel=128M@16M  quiet console=tty1
          console=ttyS1,115200 panic=30 transparent_hugepage=never
          initrd /initrd-2.6.18-274.3.1.el5.img
```

On systems that use `grub2`, use the system utility `grubby`. This command adds the parameter when run as root.

```
# grubby --update-kernel=ALL --args="transparent_hugepage=never"
```

After adding the parameter, reboot the system.

For Ubuntu systems, install the `hugepages` package and run this command as root:

```
# hugeadm --thp-never
```

This cat command checks the state of THP. The output indicates that THP is deactivated.

```
$ cat /sys/kernel/mm/*transparent_hugepage/enabled
always [never]
```

For more information about Transparent Huge Pages or the `grubby` utility, see your operating system documentation. If the `grubby` command does not update the kernels, see the Note at the end of the section.

IPC Object Removal

Deactivate IPC object removal. The default `systemd` setting `RemoveIPC=yes` removes IPC connections when non-system user accounts log out. This causes the WarehousePG utility `gpinitsystem` to fail with semaphore errors. Perform one of the following to avoid this issue.

- When you add the `gpadmin` operating system user account to the coordinator node in Creating the WarehousePG Administrative User, create the user as a system account.
- Deactivate `RemoveIPC`. Set this parameter in `/etc/systemd/logind.conf` on the WarehousePG host systems.

  ```
  RemoveIPC=no
  ```

  The setting takes effect after restarting the `systemd-login` service or rebooting the system. To restart the service, run this command as the root user.

  ```
  service systemd-logind restart
  ```

SSH Connection Threshold

Certain WarehousePG management utilities including `gpexpand`, `gpinitsystem`, and `gpaddmirrors`, use secure shell (SSH) connections between systems to perform their tasks. In large WarehousePG deployments, cloud deployments, or deployments with a large number of segments per host, these utilities may exceed the host's maximum threshold for unauthenticated connections. When this occurs, you receive errors such as: `ssh_exchange_identification: Connection closed by remote host`.

To increase this connection threshold for your WarehousePG cluster, update the SSH `MaxStartups` and `MaxSessions` configuration parameters in one of the `/etc/ssh/sshd_config` or `/etc/sshd_config` SSH daemon configuration files.

> **Note** You must have root permission to edit these two files.

If you specify `MaxStartups` and `MaxSessions` using a single integer value, you identify the maximum number of concurrent unauthenticated connections (`MaxStartups`) and maximum number of open shell, login, or subsystem sessions permitted per network connection (`MaxSessions`). For example:

```
MaxStartups 200
MaxSessions 200
```

If you specify `MaxStartups` using the "start:rate:full" syntax, you enable random early connection drop by the SSH daemon. start identifies the maximum number of unauthenticated SSH connection attempts allowed. Once start number of unauthenticated connection attempts is reached, the SSH daemon refuses rate percent of subsequent connection attempts. full identifies the maximum number of unauthenticated connection attempts after which all attempts are refused. For example:

```
Max Startups 10:30:200
MaxSessions 200
```

Restart the SSH daemon after you update `MaxStartups` and `MaxSessions`. For example, on a CentOS 6 system, run the following command as the `root` user:

```
# service sshd restart
```

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For detailed information about SSH configuration options, refer to the SSH documentation for your Linux distribution.

> **Note** If the `grubby` command does not update the kernels of a RHEL 7.x or CentOS 7.x system, you can manually update all kernels on the system. For example, to add the parameter `transparent_hugepage=never` to all kernels on a system.

1. Add the parameter to the `GRUB_CMDLINE_LINUX` line in the file parameter in `/etc/default/grub`.

   ```
   GRUB_TIMEOUT=5
   GRUB_DISTRIBUTOR="$(sed 's, release .*$,,g' /etc/system-release)"
   GRUB_DEFAULT=saved
   GRUB_DISABLE_SUBMENU=true
   GRUB_TERMINAL_OUTPUT="console"
   GRUB_CMDLINE_LINUX="crashkernel=auto rd.lvm.lv=cl/root rd.lvm.lv=cl/swap rhgb quiet transparent_hugepage=never"
                GRUB_DISABLE_RECOVERY="true"
   ```

   > **Note** You must have root permission to edit the `/etc/default/grub` file.

2. As root, run the `grub2-mkconfig` command to update the kernels.

   ```
   # grub2-mkconfig -o /boot/grub2/grub.cfg
   ```

3. Reboot the system.

Synchronizing System Clocks

You must use NTP (Network Time Protocol) to synchronize the system clocks on all hosts that comprise your WarehousePG cluster. Accurate time keeping is essential to ensure reliable operations on the database and data integrity.

There are many different architectures you may choose from to implement NTP. We recommend you use one of the following:

- Configure coordinator as the NTP primary source and the other hosts in the cluster connect to it.
- Configure an external NTP primary source and all hosts in the cluster connect to it.

Depending on your operating system version, the NTP protocol may be implemented by the `ntpd` daemon, the `chronyd` daemon, or other. Refer to your preferred NTP protocol documentation for more details.

Option 1: Configure System Clocks with the Coordinator as the Primary Source

1. On the coordinator host, log in as root and edit your NTP daemon configuration file. Set the `server` parameter to point to your data center's NTP time server. For example (if `10.6.220.20` was the IP address of your data center's NTP server):

   ```
   server 10.6.220.20
   ```

2. On each segment host, log in as root and edit your NTP daemon configuration file. Set the first `server` parameter to point to the coordinator host, and the second server parameter to point to the standby coordinator host. For example:

   ```
   server cdw prefer
   server scdw
   ```

3. On the standby coordinator host, log in as root and edit your NTP daemon configuration file. Set the first `server` parameter to point to the primary coordinator host, and the second server parameter to point to your data center's NTP time server. For example:

   ```
   server cdw prefer
   server 10.6.220.20
   ```

4. Synchronize the system clocks on all WarehousePG hosts as root.

   If you are using the `ntpd` daemon:

   ```
   systemctl restart ntp
   ```

   If you are using the `chronyd` daemon:

   ```
   systemctl restart chronyd
   ```

Option 2: Configure System Clocks with an External Primary Source

1. On each host, including coordinator, standby coordinator, and segments, log in as root and edit your NTP daemon configuration file. Set the first `server` parameter to point to your data center's NTP time server. For example (if `10.6.220.20` was the IP address of your data center's NTP server):

   ```
   server 10.6.220.20
   ```

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2. On the coordinator host, use your NTP daemon to synchronize the system clocks on all WarehousePG hosts. For example, usinggpssh:

   If you are using the `ntpd` daemon:

   ```
   gpssh -f hostfile_gpssh_allhosts -v -e 'ntpd'
   ```

   If you are using the `chronyd` daemon:

   ```
   gpssh -f hostfile_gpssh_allhosts -v -e 'chronyd'
   ```

Creating the WarehousePG Administrative User

Create a dedicated operating system user account on each node to run and administer WarehousePG. This user account is named `gpadmin` by convention.

> **Important** You cannot run the WarehousePG server as `root`.

The `gpadmin` user must have permission to access the services and directories required to install and run WarehousePG.

The `gpadmin` user on each WarehousePG host must have an SSH key pair installed and be able to SSH from any host in the cluster to any other host in the cluster without entering a password or passphrase (called "passwordless SSH"). If you enable passwordless SSH from the coordinator host to every other host in the cluster ("1-*n* passwordless SSH"), you can use the WarehousePG `gpssh-exkeys` command-line utility later to enable passwordless SSH from every host to every other host ("*n*-*n* passwordless SSH").

You can optionally give the `gpadmin` user sudo privilege, so that you can easily administer all hosts in the WarehousePG cluster as `gpadmin` using the `sudo`, `ssh/rsync`, and `gpssh/gpsync` commands.

The following steps show how to set up the `gpadmin` user on a host, set a password, create an SSH key pair, and (optionally) enable sudo capability. These steps must be performed as root on every WarehousePG cluster host. (For a large WarehousePG cluster you will want to automate these steps using your system provisioning tools.)

1. Create the `gpadmin` group and user.

   > **Note** If you are installing WarehousePG on RHEL 7.2 or CentOS 7.2 and want to deactivate IPC object removal by creating the `gpadmin` user as a system account, provide both the `-r` option (create the user as a system account) and the `-m` option (create a home directory) to the `useradd` command. On Ubuntu systems, you must use the `-m` option with the `useradd` command to create a home directory for a user.

   This example creates the `gpadmin` group, creates the `gpadmin` user as a system account with a home directory and as a member of the `gpadmin` group, and creates a password for the user.

   ```
   # groupadd gpadmin
   # useradd gpadmin -r -m -g gpadmin
   # passwd gpadmin
   New password: <changeme>
   Retype new password: <changeme>
   ```

   > **Note** You must have root permission to create the `gpadmin` group and user.

   > **Note** Make sure the `gpadmin` user has the same user id (uid) and group id (gid) numbers on each host to prevent problems with scripts or services that use them for identity or permissions. For example, backing up WarehousePGs to some networked filesy stems or storage appliances could fail if the `gpadmin` user has different uid or gid numbers on different segment hosts. When you create the `gpadmin` group and user, you can use the `groupadd -g` option to specify a gid number and the `useradd -u` option to specify the uid number. Use the command `id gpadmin` to see the uid and gid for the `gpadmin` user on the current host.

2. Switch to the `gpadmin` user and generate an SSH key pair for the `gpadmin` user.

   ```
   $ su gpadmin
   $ ssh-keygen -t rsa -b 4096
   Generating public/private rsa key pair.
   Enter file in which to save the key (/home/gpadmin/.ssh/id_rsa):
   Created directory '/home/gpadmin/.ssh'.
   Enter passphrase (empty for no passphrase):
   Enter same passphrase again:
   ```

   At the passphrase prompts, press Enter so that SSH connections will not require entry of a passphrase.

3. Grant sudo access to the `gpadmin` user.

   On Red Hat or CentOS, run `visudo` and uncomment the `%wheel` group entry.

   ```
   %wheel        ALL=(ALL)       NOPASSWD: ALL
   ```

   Make sure you uncomment the line that has the `NOPASSWD` keyword.

   Add the `gpadmin` user to the `wheel` group with this command.

   ```
   # usermod -aG wheel gpadmin
   ```

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Next Steps

- Installing WarehousePG Software
- Validating the WHPG Cluster
- Initializing WarehousePG

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3.4 Installing EDB Postgres AI for WarehousePG

WarehousePG software is a downloadable package that you install on each host system using your operating system's package management system. You must install WarehousePG on each host machine of the WarehousePG cluster.

Perform the following tasks in order:

1. Install EDB Postgres AI for WarehousePG
2. Enable passwordless SSH
3. Verify your installation

> **Note**
>
> Starting from WarehousePG 7.4, the default installation directory is `/usr/edb/whpg7`. For backward compatibility, symlinks are provided at `/usr/local/greenplum-db` and `/usr/local/greenplum-db-clients`.

Before you begin installing WarehousePG, be sure you have completed the steps inConfigure operating system to configure each of the coordinator, standby coordinator, and segment host machines for WarehousePG.

> **Important**
>
> You require sudo or root user access to install from a pre-built RPM file.

Installing EDB Postgres AI for WarehousePG

To install, you will need an EDB Subscription Token. This token is available, once logged in with your EDB account from theEDB repositories.

Save the EDB Subscription token in an environment variable:

```
export EDB_SUBSCRIPTION_TOKEN=<your-token>
```

Run the following command to add the EDB repository to your system:

```
curl -1sSLf "https://downloads.enterprisedb.com/$EDB_SUBSCRIPTION_TOKEN/gpsupp/setup.rpm.sh" | sudo -E bash
```

> **Important**
>
> Starting with WarehousePG 7.4, the `warehouse-pg-7-clients` package is mandatory and must be installed alongside the server package.

Install the EPEL repository and Warehouse-pg packages according to your operating system:

```
sudo dnf -y install https://dl.fedoraproject.org/pub/epel/epel-release-latest-
8.noarch.rpm
sudo dnf install -y warehouse-pg-7 warehouse-pg-7-
clients
```

```
sudo dnf -y install https://dl.fedoraproject.org/pub/epel/epel-release-latest-
9.noarch.rpm
sudo dnf install -y warehouse-pg-7 warehouse-pg-7-
clients
```

Change the owner and group of the installed files to `gpadmin`:

```
sudo chown -R gpadmin:gpadmin /usr/edb/whpg*
```

Enabling passwordless SSH

The `gpadmin` user on each WarehousePG host must be able to connect from any host in the cluster to any other host in the cluster without entering a password or passphrase (called "passwordless SSH"). If you enable passwordless SSH from the coordinator host to every other host in the cluster ("1-*n* passwordless SSH"), you can use the WarehousePG `gpssh-exkeys` command-line utility to enable passwordless SSH from every host to every other host ("*n*-*n* passwordless SSH").

1. Log in to the coordinator host as the `gpadmin` user.

2. Source the `path` file in the WarehousePG installation directory.

   ```
   source /usr/edb/whpg7/greenplum_path.sh
   source /usr/edb/whpg7/greenplum_clients_path.sh
   ```

   > **Note**
   >
   > Add the above `source` command to the `gpadmin` user's `.bashrc` or other shell startup file so that the WarehousePG path and environment variables are set whenever you log in as `gpadmin`.

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3. Use the `ssh-copy-id` command to add the `gpadmin` user's public key to the `authorized_hosts` SSH file on every other host in the cluster.

```
ssh-copy-id scdw
ssh-copy-id sdw1
ssh-copy-id sdw2
ssh-copy-id sdw3
. .
.
```

   This enables 1-*n* passwordless SSH. You will be prompted to enter the `gpadmin` user's password for each host. If you have the `sshpass` command on your system, you can use a command like the following to avoid the prompt.

```
SSHPASS=<password> sshpass -e ssh-copy-id scdw
```

4. In the `gpadmin` home directory, create a file named `hostfile_exkeys` that has the machine configured host names and host addresses (interface names) for each host in your WarehousePG cluster (coordinator, standby coordinator, and segment hosts). Make sure there are no blank lines or extra spaces. Check the `/etc/hosts` file on your systems for the correct host names to use for your environment. For example, if you have a coordinator, standby coordinator, and three segment hosts with two unbonded network interfaces per host, your file would look something like this:

```
cdw
cdw-1
cdw-2
scdw
scdw-1
scdw-2
sdw1
sdw1-1
sdw1-2
sdw2
sdw2-1
sdw2-2
sdw3
sdw3-1
sdw3-2
```

5. Run the `gpssh-exkeys` utility with your `hostfile_exkeys` file to enable *n*-*n* passwordless SSH for the `gpadmin` user.

```
gpssh-exkeys -f hostfile_exkeys
```

Verifying your installation

To make sure the WarehousePG software was installed and configured correctly, run the following confirmation steps from your WarehousePG coordinator host. If necessary, correct any problems before continuing on to the next task.

1. Log in to the coordinator host as `gpadmin`:

```
su - gpadmin
```

2. Use the `gpssh` utility to see if you can log in to all hosts without a password prompt, and to confirm that the WarehousePG software was installed on all hosts. Use the `hostfile_exkeys` file you used to set up passwordless SSH. For example:

```
gpssh -f hostfile_exkeys -e 'ls -l
/usr/edb/whpg7'
```

   If the installation was successful, you should be able to log in to all hosts without a password prompt. All hosts should show that they have the same contents in their installation directories, and that the directories are owned by the `gpadmin` user.

   If you are prompted for a password, run the following command to redo the ssh key exchange:

```
gpssh-exkeys -f hostfile_exkeys
```

WarehousePG installation files and directories

The following files and directories are included with your WarehousePG installation:

- `greenplum_path.sh` — This file contains the environment variables for WarehousePG. See Setting WarehousePG environment variables.
- **bin** — This directory contains the WarehousePG management utilities. This directory also contains the PostgreSQL client and server programs, most of which are also used in WarehousePG.
- **docs/cli_help** — This directory contains help files for WarehousePG command-line utilities.
- **docs/cli_help/gpconfigs** — This directory contains sample `gpinitsystem` configuration files and host files that can be modified and used when installing and initializing WarehousePG.
- **ext** — Bundled programs (such as Python) used by some WarehousePG utilities.
- **include** — The C header files for WarehousePG.
- **lib** — WarehousePG and PostgreSQL library files.
- **sbin** — Supporting/Internal scripts and programs.
- **share** — Shared files for WarehousePG.

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Next steps

Perform the following steps once your installation of WarehousePG is complete:

- Create the data storage areas
- Validate the WHPG cluster
- Initialize WarehousePG

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3.5 Creating the Data Storage Areas

Describes how to create the directory locations where WarehousePG data is stored for each coordinator, standby, and segment instance.

Parent topic: Installing and Upgrading WarehousePG

Creating Data Storage Areas on the Coordinator and Standby Coordinator Hosts

A data storage area is required on the WarehousePG coordinator and standby coordinator hosts to store WarehousePG cluster data such as catalog data and other system metadata.

To create the data directory location on the coordinator

The data directory location on the coordinator is different than those on the segments. The coordinator does not store any user data, only the system catalog tables and system metadata are stored on the coordinator instance, therefore you do not need to designate as much storage space as on the segments.

1. Create or choose a directory that will serve as your coordinator data storage area. This directory should have sufficient disk space for your data and be owned by the `gpadmin` user and group. For example, run the following commands as `root`:

   ```
   # mkdir -p /data/coordinator
   ```

2. Change ownership of this directory to the `gpadmin` user. For example:

   ```
   # chown gpadmin:gpadmin /data/coordinator
   ```

3. Using gpssh, create the coordinator data directory location on your standby coordinator as well. For example:

   ```
   # source /usr/edb/whpg7/greenplum_path.sh
   # gpssh -h scdw -e 'mkdir -p /data/coordinator'
   # gpssh -h scdw -e 'chown gpadmin:gpadmin /data/coordinator'
   ```

Creating Data Storage Areas on Segment Hosts

Data storage areas are required on the WarehousePG segment hosts for primary segments. Separate storage areas are required for mirror segments.

To create the data directory locations on all segment hosts

1. On the coordinator host, log in as `root`:

   ```
   # su
   ```

2. Create a file called `hostfile_gpssh_segonly`. This file should have only one machine configured host name for each segment host. For example, if you have three segment hosts:

   ```
   sdw1
   sdw2
   sdw3
   ```

3. Using gpssh, create the primary and mirror data directory locations on all segment hosts at once using the `hostfile_gpssh_segonly` file you just created. For example:

   ```
   # source /usr/edb/whpg7/greenplum_path.sh
   # gpssh -f hostfile_gpssh_segonly -e 'mkdir -p /data1/primary'
   # gpssh -f hostfile_gpssh_segonly -e 'mkdir -p /data2/primary'
   # gpssh -f hostfile_gpssh_segonly -e 'mkdir -p /data1/mirror'
   # gpssh -f hostfile_gpssh_segonly -e 'mkdir -p /data2/mirror'
   # gpssh -f hostfile_gpssh_segonly -e 'chown -R gpadmin /data*/*'
   ```

Next Steps

- Validating the WHPG Cluster
- Initializing WarehousePG

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3.6 Validating the WHPG Cluster

Validate your hardware and network performance.

WarehousePG provides a management utility called gpcheckperf, which can be used to identify hardware and system-level issues on the machines in your WarehousePG cluster. gpcheckperf starts a session on the specified hosts and runs the following performance tests:

- Network Performance (`gpnetbench*`)
- Disk I/O Performance (`dd` test)
- Memory Bandwidth (`stream` test)

Before using `gpcheckperf`, you must have a trusted host setup between the hosts involved in the performance test. You can use the utility gpssh-exkeys to update the known host files and exchange public keys between hosts if you have not done so already. Note that `gpcheckperf` calls to gpssh and gpsync, so these WarehousePG utilities must be in your `$PATH`.

- **Validating Network Performance**
- **Validating Disk I/O and Memory Bandwidth**

Parent topic: Installing and Upgrading WarehousePG

Validating Network Performance

To test network performance, run gpcheckperf with one of the network test run options: parallel pair test (`-r N`), serial pair test (`-r n`), or full matrix test (`-r M`). The utility runs a network benchmark program that transfers a 5 second stream of data from the current host to each remote host included in the test. By default, the data is transferred in parallel to each remote host and the minimum, maximum, average and median network transfer rates are reported in megabytes (MB) per second. If the summary transfer rate is slower than expected (less than 100 MB/s), you can run the network test serially using the `-r n` option to obtain per-host results. To run a full-matrix bandwidth test, you can specify `-r M` which will cause every host to send and receive data from every other host specified. This test is best used to validate if the switch fabric can tolerate a full-matrix workload.

Most systems in a WarehousePG cluster are configured with multiple network interface cards (NICs), each NIC on its own subnet. When testing network performance, it is important to test each subnet individually. For example, considering the following network configuration of two NICs per host:

WarehousePG Host	Subnet1 NICs	Subnet2 NICs
Segment 1	sdw1-1	sdw1-2
Segment 2	sdw2-1	sdw2-2
Segment 3	sdw3-1	sdw3-2

You would create four distinct host files for use with the gpcheckperf network test:

hostfile_gpchecknet_ic1	hostfile_gpchecknet_ic2
sdw1-1	sdw1-2
sdw2-1	sdw2-2
sdw3-1	sdw3-2

You would then run gpcheckperf once per subnet. For example (if testing an *even* number of hosts, run in parallel pairs test mode):

```
$ gpcheckperf -f hostfile_gpchecknet_ic1 -r N -d /tmp > subnet1.out
$ gpcheckperf -f hostfile_gpchecknet_ic2 -r N -d /tmp > subnet2.out
```

If you have an *odd* number of hosts to test, you can run in serial test mode (`-r n`).

Parent topic: Validating the WHPG Cluster

Validating Disk I/O and Memory Bandwidth

To test disk and memory bandwidth performance, run gpcheckperf with the disk and stream test run options (`-r ds`). The disk test uses the `dd` command (a standard UNIX utility) to test the sequential throughput performance of a logical disk or file system. The memory test uses the STREAM benchmark program to measure sustainable memory bandwidth. Results are reported in MB per second (MB/s).

To run the disk and stream tests

1. Log in on the coordinator host as the `gpadmin` user.
2. Source the `greenplum_path.sh` path file from your WarehousePG installation. For example:

   ```
   $ source /usr/edb/whpg7/greenplum_path.sh
   ```

3. Create a host file named `hostfile_gpcheckperf` that has one host name per segment host. Do not include the coordinator host. For example:

   ```
   sdw1
   sdw2
   sdw3
   sdw4
   ```

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4. Run the `gpcheckperf` utility using the `hostfile_gpcheckperf` file you just created. Use the `-d` option to specify the file systems you want to test on each host (you must have write access to these directories). You will want to test all primary and mirror segment data directory locations. For example:

```
$ gpcheckperf -f hostfile_gpcheckperf -r ds -D \
  -d /data1/primary -d  /data2/primary \
  -d /data1/mirror -d  /data2/mirror
```

5. The utility may take a while to perform the tests as it is copying very large files between the hosts. When it is finished you will see the summary results for the Disk Write, Disk Read, and Stream tests.

Parent topic: Validating the WHPG Cluster

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3.7 Initializing WarehousePG

Describes how to initialize a WarehousePG database system.

The instructions in this chapter assume you have already prepared your hosts as described in Configure Operating System and installed the WarehousePG software on all of the hosts in the system according to the instructions in Installing WarehousePG.

This chapter contains the following topics:

- Overview
- Initializing WarehousePG
- Setting WarehousePG Environment Variables
- Next Steps

Parent topic: Installing and Upgrading WarehousePG

Overview

Because WarehousePG is distributed, the process for initializing a WarehousePG management system (DBMS) involves initializing several individual PostgreSQL database instances (called *segment instances* in WarehousePG).

Each database instance (the coordinator and all segments) must be initialized across all of the hosts in the system in such a way that they can all work together as a unified DBMS. WarehousePG provides its own version of `initdb` called gpinitsystem, which takes care of initializing the database on the coordinator and on each segment instance, and starting each instance in the correct order.

After the WarehousePG database system has been initialized and started, you can then create and manage databases as you would in a regular PostgreSQL DBMS by connecting to the WarehousePG coordinator.

Initializing WarehousePG

These are the high-level tasks for initializing WarehousePG:

1. Make sure you have completed all of the installation tasks described in Configure Operating System and Installing WarehousePG.
2. Create a host file that contains the host addresses of your segments. See Creating the Initialization Host File.
3. Create your WarehousePG cluster configuration file. See Creating the WarehousePG Configuration File.
4. By default, WarehousePG will be initialized using the locale of the coordinator host system. Make sure this is the correct locale you want to use, as some locale options cannot be changed after initialization. See Configuring Timezone and Localization Settings for more information.
5. Run the WarehousePG initialization utility on the coordinator host. See Running the Initialization Utility.
6. Set the WarehousePG timezone. See Setting the WarehousePG Timezone.
7. Set environment variables for the WarehousePG user. See Setting WarehousePG Environment Variables.

When performing the following initialization tasks, you must be logged into the coordinator host as the `gpadmin` user, and to run WarehousePG utilities, you must source the `greenplum_path.sh` file to set WarehousePG environment variables. For example, if you are logged into the coordinator, run these commands.

```
$ su - gpadmin
$ source /usr/edb/whpg7/greenplum_path.sh
```

Creating the Initialization Host File

The gpinitsystem utility requires a host file that contains the list of addresses for each segment host. The initialization utility determines the number of segment instances per host by the number host addresses listed per host times the number of data directory locations specified in the `gpinitsystem_config` file.

This file should only contain segment host addresses (not the coordinator or standby coordinator). For segment machines with multiple, unbonded network interfaces, this file should list the host address names for each interface — one per line.

> **Note** The WarehousePG segment host naming convention is sdwN where sdw is a prefix and N is an integer. For example, `sdw2` and so on. If hosts have multiple unbonded NICs, the convention is to append a dash (`-`) and number to the host name. For example, `sdw1-1` and `sdw1-2` are the two interface names for host `sdw1`. However, NIC bonding is recommended to create a load-balanced, fault-tolerant network.

To create the initialization host file

1. Create a file named `hostfile_gpinitsystem`. In this file add the host address name(s) of your *segment* host interfaces, one name per line, no extra lines or spaces. For example, if you have four segment hosts with two unbonded network interfaces each:

   ```
   sdw1-1
   sdw1-2
   sdw2-1
   sdw2-2
   sdw3-1
   sdw3-2
   sdw4-1
   sdw4-2
   ```

2. Save and close the file.

> **Note** If you are not sure of the host names and/or interface address names used by your machines, look in the `/etc/hosts` file.

Creating the WarehousePG Configuration File

Your WarehousePG configuration file tells the gpinitsystem utility how you want to configure your WarehousePG cluster. An example configuration file can be found in `$GPHOME/docs/cli_help/gpconfigs/gpinitsystem_config`.

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To create a gpinitsystem_config file

1. Make a copy of the `gpinitsystem_config` file to use as a starting point. For example:

   ```
   $ cp $GPHOME/docs/cli_help/gpconfigs/gpinitsystem_config \
        /home/gpadmin/gpconfigs/gpinitsystem_config
   ```

2. Open the file you just copied in a text editor.

   Set all of the required parameters according to your environment. See gpinitsystem for more information. A WarehousePG cluster must contain a coordinator instance and at *least two* segment instances (even if setting up a single node system).

   The `DATA_DIRECTORY` parameter is what determines how many segments per host will be created. If your segment hosts have multiple network interfaces, and you used their interface address names in your host file, the number of segments will be evenly spread over the number of available interfaces.

   To specify `PORT_BASE`, review the port range specified in the `net.ipv4.ip_local_port_range` parameter in the `/etc/sysctl.conf` file. See Recommended OS Parameters Settings.

   Here is an example of the *required* parameters in the `gpinitsystem_config` file:

   ```
   SEG_PREFIX=gpseg
   PORT_BASE=6000
   declare -a DATA_DIRECTORY=(/data1/primary /data1/primary /data1/primary /data2/primary /data2/primary /data2/primary)
   COORDINATOR_HOSTNAME=cdw
   COORDINATOR_DIRECTORY=/data/coordinator
   COORDINATOR_PORT=5432
   TRUSTED SHELL=ssh
   CHECK_POINT_SEGMENTS=8
   ENCODING=UNICODE
   ```

3. (Optional) If you want to deploy mirror segments, uncomment and set the mirroring parameters according to your environment. To specify `MIRROR_PORT_BASE`, review the port range specified under the `net.ipv4.ip_local_port_range` parameter in the `/etc/sysctl.conf` file. Here is an example of the *optional* mirror parameters in the `gpinitsystem_config` file:

   ```
   MIRROR_PORT_BASE=7000
   declare -a MIRROR_DATA_DIRECTORY=(/data1/mirror /data1/mirror /data1/mirror /data2/mirror /data2/mirror /data2/mirror)
   ```

   > **Note** You can initialize your WarehousePG cluster with primary segments only and deploy mirrors later using the gpaddmirrors utility.

4. Save and close the file.

Running the Initialization Utility

The gpinitsystem utility will create a WarehousePG cluster using the values defined in the configuration file.

These steps assume you are logged in as the `gpadmin` user and have sourced the `greenplum_path.sh` file to set WarehousePG environment variables.

To run the initialization utility

1. Run the following command referencing the path and file name of your initialization configuration file (`gpinitsystem_config`) and host file (`hostfile_gpinitsystem`). For example:

   ```
   $ cd ~
   $ gpinitsystem -c gpconfigs/gpinitsystem_config -h gpconfigs/hostfile_gpinitsystem
   ```

   For a fully redundant system (with a standby coordinator and a *spread* mirror configuration) include the `-s` and `--mirror-mode=spread` options. For example:

   ```
   $ gpinitsystem -c gpconfigs/gpinitsystem_config -h gpconfigs/hostfile_gpinitsystem \
     -s <standby_coordinator_hostname> --mirror-mode=spread
   ```

   During a new cluster creation, you may use the `-O output\_configuration\_file` option to save the cluster configuration details in a file. For example:

   ```
   $ gpinitsystem -c gpconfigs/gpinitsystem_config -O gpconfigs/config_template
   ```

   This output file can be edited and used at a later stage as the input file of the `-I` option, to create a new cluster or to recover from a backup. See gpinitsystem for further details.

   > **Note** Calling `gpinitsystem` with the `-O` option does not initialize the WarehousePG cluster; it merely generates and saves a file with cluster configuration details.

2. The utility will verify your setup information and make sure it can connect to each host and access the data directories specified in your configuration. If all of the pre-checks are successful, the utility will prompt you to confirm your configuration. For example:

   ```
   => Continue with WarehousePG creation? Yy/Nn
   ```

3. Press `y` to start the initialization.

4. The utility will then begin setup and initialization of the coordinator instance and each segment instance in the system. Each segment instance is set up in parallel. Depending on the number of segments, this process can take a while.

5. At the end of a successful setup, the utility will start your WarehousePG cluster. You should see:

   ```
   => WarehousePG instance successfully created.
   ```

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Troubleshooting Initialization Problems

If the utility encounters any errors while setting up an instance, the entire process will fail, and could possibly leave you with a partially created system. Refer to the error messages and logs to determine the cause of the failure and where in the process the failure occurred. Log files are created in `~/gpAdminLogs`.

Depending on when the error occurred in the process, you may need to clean up and then try the `gpinitsystem` utility again. For example, if some segment instances were created and some failed, you may need to stop `postgres` processes and remove any utility-created data directories from your data storage area(s). A backout script is created to help with this cleanup if necessary.

Using the Backout Script

If the gpinitsystem utility fails, it will create the following backout script if it has left your system in a partially installed state:

```
~/gpAdminLogs/backout_gpinitsystem_<user>_<timestamp>
```

You can use this script to clean up a partially created WarehousePG cluster. This backout script will remove any utility-created data directories, `postgres` processes, and log files. After correcting the error that caused `gpinitsystem` to fail and running the backout script, you should be ready to retry initializing your WarehousePG cluster.

The following example shows how to run the backout script:

```
$ bash ~/gpAdminLogs/backout_gpinitsystem_gpadmin_20071031_121053
```

Setting the WarehousePG Timezone

As a best practice, configure WarehousePG and the host systems to use a known, supported timezone. WarehousePG uses a timezone from a set of internally stored PostgreSQL timezones. Setting the WarehousePG timezone prevents WarehousePG from selecting a timezone each time the cluster is restarted and sets the timezone for the WarehousePG coordinator and segment instances.

Use the gpconfig utility to show and set the WarehousePG timezone. For example, these commands show the WarehousePG timezone and set the timezone to `US/Pacific`.

```
$ gpconfig -s TimeZone
$ gpconfig -c TimeZone -v 'US/Pacific'
```

You must restart WarehousePG after changing the timezone. The command `gpstop -ra` restarts WarehousePG. The catalog view `pg_timezone_names` provides WarehousePG timezone information.

For more information about the WarehousePG timezone, see Configuring Timezone and Localization Settings.

Setting WarehousePG Environment Variables

You must set environment variables in the WarehousePG user (`gpadmin`) environment that runs WarehousePG on the WarehousePG coordinator and standby coordinator hosts. A `greenplum_path.sh` file is provided in the WarehousePG installation directory with environment variable settings for WarehousePG.

The WarehousePG management utilities also require that the `COORDINATOR_DATA_DIRECTORY` environment variable be set. This should point to the directory created by the `gpinitsystem` utility in the coordinator data directory location.

> **Note** The `greenplum_path.sh` script changes the operating environment in order to support running the WarehousePG-specific utilities. These same changes to the environment can negatively affect the operation of other system-level utilities, such as `ps` or `yum`. Use separate accounts for performing system administration and database administration, instead of attempting to perform both functions as `gpadmin`.

These steps ensure that the environment variables are set for the `gpadmin` user after a system reboot.

To set up the gpadmin environment for WarehousePG

1. Open the `gpadmin` profile file (such as `.bashrc`) in a text editor. For example:

   ```
   $ vi ~/.bashrc
   ```

2. Add lines to this file to source the `greenplum_path.sh` file and set the `COORDINATOR_DATA_DIRECTORY` environment variable. For example:

   ```
   source /usr/edb/whpg7/greenplum_path.sh
   export COORDINATOR_DATA_DIRECTORY=/data/coordinator/gpseg-1
   ```

3. (Optional) You may also want to set some client session environment variables such as `PGPORT`, `PGUSER` and `PGDATABASE` for convenience. For example:

   ```
   export PGPORT=5432
   export PGUSER=gpadmin
   export PGDATABASE=gpadmin
   ```

4. (Optional) If you use RHEL/Oracle/Rocky Linux, add the following line to the end of the `.bashrc` file to enable using the `ps` command in the `greenplum_path.sh` environment:

   ```
   export LD_PRELOAD=/lib64/libz.so.1 ps
   ```

5. Save and close the file.

6. After editing the profile file, source it to make the changes active. For example:

   ```
   $ source ~/.bashrc
   ```

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7. If you have a standby coordinator host, copy your environment file to the standby coordinator as well. For example:

```
$ cd ~
$ scp .bashrc <standby_hostname>:`pwd`
```

Note The `.bashrc` file should not produce any output. If you wish to have a message display to users upon logging in, use the `.bash_profile` file instead.

Next Steps

After your system is up and running, the next steps are:

- Allowing Client Connections
- Creating Databases and Loading Data

Allowing Client Connections

After a WarehousePG is first initialized it will only allow local connections to the database from the `gpadmin` role (or whatever system user ran `gpinitsystem`). If you would like other users or client machines to be able to connect to WarehousePG, you must give them access. See the *WarehousePG Administrator Guide* for more information.

Creating Databases and Loading Data

After verifying your installation, you may want to begin creating databases and loading data. See DDL: Defining Database Objects and Loading and Unloading Data in the *WarehousePG Administrator Guide* for more information about creating databases, schemas, tables, and other database objects in WarehousePG and loading your data.

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3.8 Installing Optional Extensions

Information about installing optional WarehousePG extensions and packages, such as the Procedural Language extensions and the Python and R Data Science Packages.

- Procedural Language, Machine Learning, and Geospatial Extensions
- Python Data Science Module Package
- R Data Science Library Package
- WarehousePG Platform Extension Framework (PXF)

Parent topic: Installing and Upgrading WarehousePG

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3.8.1 Procedural Language, Machine Learning, and Geospatial Extensions

The extension documentation in the *WarehousePG Reference Guide* contains information about installing extension packages and using extensions.

- WarehousePG PL/R Language Extension
- WarehousePG PL/Java Language Extension
- WarehousePG MADlib Extension for Analytics
- WarehousePG PostGIS Extension
- WarehousePG H3 Extension

Parent topic: Installing Optional Extensions (WarehousePG)

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3.8.2 WarehousePG Platform Extension Framework (PXF)

Optional. If you do not plan to use PXF, no action is necessary.

If you plan to use PXF, refer to Accessing External Data with PXF for introductory PXF information.

Parent topic: Installing Optional Extensions (WarehousePG)

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3.8.3 Data Science Package for Python

WarehousePG provides a collection of data science-related Python modules that can be used with the WarehousePG PL/Python language. This section contains the following information:

- Data Science Package for Python 3.11 Modules
- Installing a Data Science Package for Python
- Uninstalling a Data Science Package for Python

For information about the WarehousePG PL/Python Language, see WarehousePG PL/Python Language Extension.

Parent topic: Installing Optional Extensions (WarehousePG)

Data Science Package for Python 3.11 Modules

The following table lists the modules that are provided in the Data Science Package for Python 3.11.

Module Name	Description/Used For
absl-py	Abseil Python Common Libraries
arviz	Exploratory analysis of Bayesian models
astor	Read/rewrite/write Python ASTs
astunparse	An AST unparser for Python
autograd	Efficiently computes derivatives of numpy code
autograd-gamma	autograd compatible approximations to the derivatives of the Gamma-family of functions
backports.csv	Backport of Python 3 csv module
beautifulsoup4	Screen-scraping library
blis	The Blis BLAS-like linear algebra library, as a self-contained C-extension
cachetools	Extensible memoizing collections and decorators
catalogue	Super lightweight function registries for your library
catboost	A high-performance open source library for gradient boosting on decision trees
certifi	Python package for providing Mozilla's CA Bundle
cffi	Foreign Function Interface for Python calling C code
cftime	Time-handling functionality from netcdf4-python
charset-normalizer	The Real First Universal Charset Detector. Open, modern and actively maintained alternative to Chardet.
cheroot	Highly-optimized, pure-python HTTP server
CherryPy	Object-Oriented HTTP framework
click	Composable command line interface toolkit
convertdate	Converts between Gregorian dates and other calendar systems
cryptography	A set of functions useful in cryptography and linear algebra
cycler	Composable style cycles
cymem	Manage calls to calloc/free through Cython
Cython	The Cython compiler for writing C extensions for the Python language
datasets	HuggingFace community-driven open-source library of datasets
deprecat	Python @deprecat decorator to deprecate old python classes, functions or methods
dill	serialize all of python
fastprogress	A nested progress with plotting options for fastai
feedparser	Universal feed parser, handles RSS 0.9x, RSS 1.0, RSS 2.0, CDF, Atom 0.3, and Atom 1.0 feeds
filelock	A platform independent file lock
flatbuffers	The FlatBuffers serialization format for Python
fonttools	Tools to manipulate font files
formulaic	An implementation of Wilkinson formulas
funcy	A fancy and practical functional tools
future	Clean single-source support for Python 3 and 2
gast	Python AST that abstracts the underlying Python version
gensim	Python framework for fast Vector Space Modelling
gluonts	GluonTS is a Python toolkit for probabilistic time series modeling, built around MXNet
google-auth	Google Authentication Library
google-auth-oauthlib	Google Authentication Library
google-pasta	pasta is an AST-based Python refactoring library
graphviz	Simple Python interface for Graphviz
greenlet	Lightweight in-process concurrent programming
grpcio	HTTP/2-based RPC framework
h5py	Read and write HDF5 files from Python
hijri-converter	Accurate Hijri-Gregorian dates converter based on the Umm al-Qura calendar
holidays	Generate and work with holidays in Python
idna	Internationalized Domain Names in Applications (IDNA)
importlib-metadata	Read metadata from Python packages
InstructorEmbedding	Text embedding tool
interface-meta	Provides a convenient way to expose an extensible API with enforced method signatures and consistent documentation
jaraco.classes	Utility functions for Python class constructs
jaraco.collections	Collection objects similar to those in stdlib by jaraco

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Module Name	Description/Used For
jaraco.context	Context managers by jaraco
jaraco.functools	Functools like those found in stdlib
jaraco.text	Module for text manipulation
Jinja2	A very fast and expressive template engine
joblib	Lightweight pipelining with Python functions
keras	Deep learning for humans
Keras-Preprocessing	Easy data preprocessing and data augmentation for deep learning models
kiwisolver	A fast implementation of the Cassowary constraint solver
korean-lunar-calendar	Korean Lunar Calendar
langcodes	Tools for labeling human languages with IETF language tags
libclang	Clang Python Bindings, mirrored from the official LLVM repo
lifelines	Survival analysis in Python, including Kaplan Meier, Nelson Aalen and regression
lime	Local Interpretable Model-Agnostic Explanations for machine learning classifiers
llvmlite	lightweight wrapper around basic LLVM functionality
lxml	Powerful and Pythonic XML processing library combining libxml2/libxslt with the ElementTree API
Markdown	Python implementation of Markdown
MarkupSafe	Safely add untrusted strings to HTML/XML markup
matplotlib	Python plotting package
more-itertools	More routines for operating on iterables, beyond itertools
murmurhash	Cython bindings for MurmurHash
mxnet	An ultra-scalable deep learning framework
mysqlclient	Python interface to MySQL
netCDF4	Provides an object-oriented python interface to the netCDF version 4 library
nltk	Natural language toolkit
numba	Compiling Python code using LLVM
numexpr	Fast numerical expression evaluator for NumPy
numpy	Scientific computing
oauthlib	A generic, spec-compliant, thorough implementation of the OAuth request-signing logic
opt-einsum	Optimizing numpys einsum function
orjson	Fast, correct Python JSON library supporting dataclasses, datetimes, and numpy
packaging	Core utilities for Python packages
pandas	Data analysis
pathy	pathlib.Path subclasses for local and cloud bucket storage
patsy	Package for describing statistical models and for building design matrices
Pattern	Web mining module for Python
pdfminer.six	PDF parser and analyzer
Pillow	Python Imaging Library
pmdarima	Python's forecast::auto.arima equivalent
portend	TCP port monitoring and discovery
preshed	Cython hash table that trusts the keys are pre-hashed
prophet	Automatic Forecasting Procedure
protobuf	Protocol buffers
psycopg2	PostgreSQL database adapter for Python
pyasn1	ASN.1 types and codecs
pyasn1-modules	pyasn1-modules
pycparser	C parser in Python
pydantic	Data validation and settings management using python type hints
pyLDAvis	Interactive topic model visualization
pymc3	Statistical modeling and probabilistic machine learning
PyMeeus	Python implementation of Jean Meeus astronomical routines
pyparsing	Python parsing
python-dateutil	Extensions to the standard Python datetime module
python-docx	Create and update Microsoft Word .docx files
PyTorch	Tensors and Dynamic neural networks in Python with strong GPU acceleration
pytz	World timezone definitions, modern and historical
PyXB-X	To generate Python code for classes that correspond to data structures defined by XMLSchema
regex	Alternative regular expression module, to replace re
requests	HTTP library
requests-oauthlib	OAuthlib authentication support for Requests
rouge	Full Python ROUGE Score Implementation (not a wrapper)
rsa	OAuthlib authentication support for Requests
sacrebleu	Hassle-free computation of shareable, comparable, and reproducible BLEU, chrF, and TER scores
scikit-learn	Machine learning data mining and analysis
scipy	Scientific computing
semver	Python helper for Semantic Versioning
sentence_transformers	Multilingual Sentence, Paragraph, and Image Embeddings using BERT & Co.
sgmllib3k	Py3k port of sgmllib
shap	A unified approach to explain the output of any machine learning model

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Module Name	Description/Used For
six	Python 2 and 3 compatibility library
sklearn	A set of python modules for machine learning and data mining
smart-open	Utilities for streaming large files (S3, HDFS, gzip, bz2, and so forth)
soupsieve	A modern CSS selector implementation for Beautiful Soup
spacy	Large scale natural language processing
spacy-legacy	Legacy registered functions for spaCy backwards compatibility
spacy-loggers	Logging utilities for SpaCy
spectrum	Spectrum Analysis Tools
SQLAlchemy	Database Abstraction Library
srsly	Modern high-performance serialization utilities for Python
statsmodels	Statistical modeling
tempora	Objects and routines pertaining to date and time
tensorboard	TensorBoard lets you watch Tensors Flow
tensorboard-data-server	Fast data loading for TensorBoard
tensorboard-plugin-wit	What-If Tool TensorBoard plugin
tensorflow	Numerical computation using data flow graphs
tensorflow-estimator	What-If Tool TensorBoard plugin
tensorflow-io-gcs-filesystem	TensorFlow IO
termcolor	simple termcolor wrapper
Theano-PyMC	Theano-PyMC
thinc	Practical Machine Learning for NLP
threadpoolctl	Python helpers to limit the number of threads used in the threadpool-backed of common native libraries used for scientific computing and data science
toolz	List processing tools and functional utilities
tqdm	Fast, extensible progress meter
transformers	State-of-the-art Machine Learning for JAX, PyTorch and TensorFlow
tslearn	A machine learning toolkit dedicated to time-series data
typer	Typer, build great CLIs. Easy to code. Based on Python type hints
typing_extensions	Backported and Experimental Type Hints for Python 3.7+
urllib3	HTTP library with thread-safe connection pooling, file post, and more
wasabi	Lightweight console printing and formatting toolkit
Werkzeug	Comprehensive WSGI web application library
wrapt	Module for decorators, wrappers and monkey patching
xarray	N-D labeled arrays and datasets in Python
xarray-einstats	Stats, linear algebra and einops for xarray
xgboost	Gradient boosting, classifying, ranking
xmltodict	Makes working with XML feel like you are working with JSON
zc.lockfile	Basic inter-process locks
zipp	Backport of pathlib-compatible object wrapper for zip files
tensorflow	Numerical computation using data flow graphs
keras	An implementation of the Keras API that uses TensorFlow as a backend

Installing a Data Science Package for Python

Before you install a Data Science Package for Python, make sure that your WarehousePG is running, you have sourced `greenplum_path.sh`, and that the `$COORDINATOR_DATA_DIRECTORY` and `$GPHOME` environment variables are set.

> **Note** The `PyMC3` module depends on `Tk`. If you want to use `PyMC3`, you must install the `tk` OS package on every node in your cluster. For example:

```
$ sudo yum install tk
```

1. Locate the Data Science Package for Python that you built or downloaded.
2. Copy the package to the WarehousePG coordinator host.
3. Install the package.
4. Restart WarehousePG. You must re-source `greenplum_path.sh` before restarting your WarehousePG cluster:

   ```
   $ source /usr/edb/whpg7/greenplum_path.sh
   $ gpstop -r
   ```

The Data Science Package for Python modules are installed in the following directory:

```
$GPHOME/ext/DataSciencePython/lib/python3.11/site-packages/
```

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Uninstalling a Data Science Package for Python

The command removes the Data Science Package for Python modules from your WarehousePG cluster. It also updates the `PYTHONPATH`, `PATH`, and `LD_LIBRARY_PATH` environment variables in your `greenplum_path.sh` file to their pre-installation values.

Re-source `greenplum_path.sh` and restart WarehousePG after you remove the Python Data Science Module package:

```
$ . /usr/edb/whpg7/greenplum_path.sh
$ gpstop -r
```

> **Note** After you uninstall a Data Science Package for Python from your WarehousePG cluster, any UDFs that you have created that import Python modules installed with this package will return an error.

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3.8.4 R Data Science Library Package

R packages are modules that contain R functions and data sets. WarehousePG provides a collection of data science-related R libraries that can be used with the WarehousePG PL/R language.

This chapter contains the following information:

- R Data Science Libraries
- Installing the R Data Science Library Package

For information about the WarehousePG PL/R Language, see WarehousePG PL/R Language Extension.

Parent topic: Installing Optional Extensions (WarehousePG)

R Data Science Libraries

Libraries provided in the R Data Science package include:

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abind	gower	quantmod
adabag	gplots	quantreg
arm	gss	R2WinBUGS
assertthat	gtable	R6
backports	gtools	randomForest
BH	hms	RColorBrewer
bitops	hybridHclust	Rcpp
car	igraph	RcppArmadillo
caret	ipred	RcppEigen
caTools	iterators	readr
cli	labeling	recipes
clipr	lattice	reshape2
coda	lava	rlang
colorspace	lazyeval	RobustRankAggreg
compHclust	lme4	ROCR
crayon	lmtest	rpart
curl	lubridate	RPostgreSQL
data.table	magrittr	sandwich
DBI	MASS	scales
Deriv	Matrix	SparseM
dichromat	MatrixModels	SQUAREM
digest	mcmc	stabledist
doParallel	MCMCpack	stringi
dplyr	minqa	stringr
e1071	ModelMetrics	survival
ellipsis	MTS	tibble
fansi	munsell	tidyr
fastICA	mvtnorm	tidyselect
fBasics	neuralnet	timeDate
fGarch	nloptr	timeSeries
flashClust	nnet	tseries
foreach	numDeriv	TTR
forecast	pbkrtest	urca
foreign	pillar	utf8
fracdiff	pkgconfig	vctrs
gdata	plogr	viridisLite
generics	plyr	withr
ggplot2	prodlim	xts
glmnet	purrr	zeallot
glue	quadprog	zoo

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Installing the R Data Science Library Package

Before you install the R Data Science Library package, make sure that your WarehousePG is running, you have sourced `greenplum_path.sh`, and that the `COORDINATOR_DATA_DIRECTORY` and `$GPHOME` environment variables are set.

1. Locate the R Data Science library package that you built or downloaded.
2. Copy the package to the WarehousePG coordinator host.
3. Install the package.
4. Restart WarehousePG. You must re-source `greenplum_path.sh` before restarting your WarehousePG cluster:

```
$ source /usr/edb/whpg7/greenplum_path.sh
$ gpstop -r
```

The WarehousePG R Data Science Modules are installed in the following directory:

```
$GPHOME/ext/DataScienceR/library
```

> **Note** When you uninstall the R Data Science Library package from your WarehousePG cluster, any UDFs that you have created that use R libraries installed with this package will return an error.

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3.9 Installing Extensions

The WarehousePG distribution includes several PostgreSQL- and WarehousePG-sourced `contrib` modules that you have the option to install.

Each module is typically packaged as a WarehousePG extension. You must register these modules in each database in which you want to use it. For example, to register the `dblink` module in the database named `testdb`, use the command:

```
$ psql -d testdb -c 'CREATE EXTENSION dblink;'
```

To remove a module from a database, drop the associated extension. For example, to remove the `dblink` module from the `testdb` database:

```
$ psql -d testdb -c 'DROP EXTENSION dblink;'
```

> **Note** When you drop a module extension from a database, any user-defined function that you created in the database that references functions defined in the module will no longer work. If you created any database objects that use data types defined in the module, WarehousePG will notify you of these dependencies when you attempt to drop the module extension.

You can register the following modules in this manner:

• btree_gin • citext • dblink • diskquota • fuzzystrmatch • gp_sparse_vector • hstore • ip4r	• ltree • orafce (WarehousePG only) • pageinspect • pg_trgm • pgcrypto • pgvector • postgres_fdw • postgresql-hll • sslinfo • tablefunc • timestamp9 • uuid-ossp

For additional information about the modules supplied with WarehousePG, refer toAdditional Supplied Modules in the *WarehousePG Reference Guide*.

Parent topic: Installing and Upgrading WarehousePG

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3.10 Configuring Timezone and Localization Settings

Describes the available timezone and localization features of WarehousePG.

Parent topic: Installing and Upgrading WarehousePG

Configuring the Timezone

WarehousePG selects a timezone to use from a set of internally stored PostgreSQL timezones. The available PostgreSQL timezones are taken from the Internet Assigned Numbers Authority (IANA) Time Zone Database, and WarehousePG updates its list of available timezones as necessary when the IANA database changes for PostgreSQL.

WarehousePG selects the timezone by matching a PostgreSQL timezone with the value of the `TimeZone` server configuration parameter, or the host system time zone if `TimeZone` is not set. For example, when selecting a default timezone from the host system time zone, WarehousePG uses an algorithm to select a PostgreSQL timezone based on the host system timezone files. If the system timezone includes leap second information, WarehousePG cannot match the system timezone with a PostgreSQL timezone. In this case, WarehousePG calculates a "best match" with a PostgreSQL timezone based on information from the host system.

As a best practice, configure WarehousePG and the host systems to use a known, supported timezone. This sets the timezone for the WarehousePG coordinator and segment instances, and prevents WarehousePG from selecting a best match timezone each time the cluster is restarted, using the current system timezone and WarehousePG timezone files (which may have been updated from the IANA database since the last restart). Use the `gpconfig` utility to show and set the WarehousePG timezone. For example, these commands show the WarehousePG timezone and set the timezone to `US/Pacific`.

```
# gpconfig -s TimeZone
# gpconfig -c TimeZone -v 'US/Pacific'
```

You must restart WarehousePG after changing the timezone. The command `gpstop -ra` restarts WarehousePG. The catalog view `pg_timezone_names` provides WarehousePG timezone information.

About Locale Support in WarehousePG

WarehousePG supports localization with two approaches:

- Using the locale features of the operating system to provide locale-specific collation order, number formatting, and so on.
- Providing a number of different character sets defined in the WarehousePG server, including multiple-byte character sets, to support storing text in all kinds of languages, and providing character set translation between client and server.

Locale support refers to an application respecting cultural preferences regarding alphabets, sorting, number formatting, etc. WarehousePG uses the standard ISO C and POSIX locale facilities provided by the server operating system. For additional information refer to the documentation of your operating system.

Locale support is automatically initialized when a WarehousePG cluster is initialized. The initialization utility, gpinitsystem, will initialize the WarehousePG cluster with the locale setting of its execution environment by default, so if your system is already set to use the locale that you want in your WarehousePG cluster then there is nothing else you need to do.

When you are ready to initiate WarehousePG and you want to use a different locale (or you are not sure which locale your system is set to), you can instruct `gpinitsystem` exactly which locale to use by specifying the -n locale option. For example:

```
$ gpinitsystem -c gp_init_config -n sv_SE
```

See Initializing WarehousePG for information about the database initialization process.

The example above sets the locale to Swedish (sv) as spoken in Sweden (SE). Other possibilities might be `en_US` (U.S. English) and `fr_CA` (French Canadian). If more than one character set can be useful for a locale then the specifications look like this: `cs_CZ.ISO8859-2`. What locales are available under what names on your system depends on what was provided by the operating system vendor and what was installed. On most systems, the command `locale -a` will provide a list of available locales.

Occasionally it is useful to mix rules from several locales, for example use English collation rules but Spanish messages. To support that, a set of locale subcategories exist that control only a certain aspect of the localization rules:

- `LC_COLLATE` — String sort order
- `LC_CTYPE` — Character classification (What is a letter? Its upper-case equivalent?)
- `LC_MESSAGES` — Language of messages
- `LC_MONETARY` — Formatting of currency amounts
- `LC_NUMERIC` — Formatting of numbers
- `LC_TIME` — Formatting of dates and times

If you want the system to behave as if it had no locale support, use the special locale `C` or `POSIX`.

The nature of some locale categories is that their value has to be fixed for the lifetime of a WarehousePG cluster. That is, once `gpinitsystem` has run, you cannot change them anymore. `LC_COLLATE` and `LC_CTYPE` are those categories. They affect the sort order of indexes, so they must be kept fixed, or indexes on text columns will become corrupt. WarehousePG enforces this by recording the values of `LC_COLLATE` and `LC_CTYPE` that are seen by gpinitsystem. The server automatically adopts those two values based on the locale that was chosen at initialization time.

The other locale categories can be changed as desired whenever the server is running by setting the server configuration parameters that have the same name as the locale categories (see the*WarehousePG Reference Guide* for more information on setting server configuration parameters). The defaults that are chosen by gpinitsystem are written into the coordinator and segment `postgresql.conf` configuration files to serve as defaults when the WarehousePG cluster is started. If you delete these assignments from the coordinator and each segment `postgresql.conf` files then the server will inherit the settings from its execution environment.

Note that the locale behavior of the server is determined by the environment variables seen by the server, not by the environment of any client. Therefore, be careful to configure the correct locale settings on each WarehousePG host (coordinator and segments) before starting the system. A consequence of this is that if client and server are set up in different locales, messages may appear in different languages depending on where they originated.

Inheriting the locale from the execution environment means the following on most operating systems: For a given locale category, say the collation, the following environment variables are consulted in this order until one is found to be set: `LC_ALL`, `LC_COLLATE` (the variable corresponding to the respective category), `LANG`. If none of these environment variables are set then the locale defaults to `C`.

Some message localization libraries also look at the environment variable `LANGUAGE` which overrides all other locale settings for the purpose of setting the language of messages. If in doubt, please refer to the documentation for your operating system, in particular the documentation about `gettext`, for more information.

Native language support (NLS), which enables messages to be translated to the user's preferred language, is not enabled in WarehousePG for languages other than English. This is independent of the other locale support.

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Locale Behavior

The locale settings influence the following SQL features:

- Sort order in queries using `ORDER BY` on textual data
- The ability to use indexes with `LIKE` clauses
- The `upper`, `lower`, and `initcap` functions
- The `to_char` family of functions

The drawback of using locales other than `C` or `POSIX` in WarehousePG is its performance impact. It slows character handling and prevents ordinary indexes from being used by `LIKE`. For this reason use locales only if you actually need them.

Troubleshooting Locales

If locale support does not work as expected, check that the locale support in your operating system is correctly configured. To check what locales are installed on your system, you may use the command `locale -a` if your operating system provides it.

Check that WarehousePG is actually using the locale that you think it is. `LC_COLLATE` and `LC_CTYPE` settings are determined at initialization time and cannot be changed without redoing gpinitsystem. Other locale settings including `LC_MESSAGES` and `LC_MONETARY` are initially determined by the operating system environment of the coordinator and/or segment host, but can be changed after initialization by editing the `postgresql.conf` file of each WarehousePG coordinator and segment instance. You can check the active locale settings of the coordinator host using the `SHOW` command. Note that every host in your WarehousePG cluster should be using identical locale settings.

Character Set Support

The character set support in WarehousePG allows you to store text in a variety of character sets, including single-byte character sets such as the ISO 8859 series and multiple-byte character sets such as EUC (Extended Unix Code), UTF-8, and Mule internal code. All supported character sets can be used transparently by clients, but a few are not supported for use within the server (that is, as a server-side encoding). The default character set is selected while initializing your WarehousePG cluster using `gpinitsystem`. It can be overridden when you create a database, so you can have multiple databases each with a different character set.

Name	Description	Language	Server?	Bytes/Char	Aliases
BIG5	Big Five	Traditional Chinese	No	1-2	WIN950, Windows950
EUC_CN	Extended UNIX Code-CN	Simplified Chinese	Yes	1-3	
EUC_JP	Extended UNIX Code-JP	Japanese	Yes	1-3	
EUC_KR	Extended UNIX Code-KR	Korean	Yes	1-3	
EUC_TW	Extended UNIX Code-TW	Traditional Chinese, Taiwanese	Yes	1-3	
GB18030	National Standard	Chinese	No	1-2	
GBK	Extended National Standard	Simplified Chinese	No	1-2	WIN936, Windows936
ISO_8859_5	ISO 8859-5, ECMA 113	Latin/Cyrillic	Yes	1	
ISO_8859_6	ISO 8859-6, ECMA 114	Latin/Arabic	Yes	1	
ISO_8859_7	ISO 8859-7, ECMA 118	Latin/Greek	Yes	1	
ISO_8859_8	ISO 8859-8, ECMA 121	Latin/Hebrew	Yes	1	
JOHAB	JOHA	Korean (Hangul)	Yes	1-3	
KOI8	KOI8-R(U)	Cyrillic	Yes	1	KOI8R
LATIN1	ISO 8859-1, ECMA 94	Western European	Yes	1	ISO88591
LATIN2	ISO 8859-2, ECMA 94	Central European	Yes	1	ISO88592
LATIN3	ISO 8859-3, ECMA 94	South European	Yes	1	ISO88593
LATIN4	ISO 8859-4, ECMA 94	North European	Yes	1	ISO88594
LATIN5	ISO 8859-9, ECMA 128	Turkish	Yes	1	ISO88599
LATIN6	ISO 8859-10, ECMA 144	Nordic	Yes	1	ISO885910
LATIN7	ISO 8859-13	Baltic	Yes	1	ISO885913
LATIN8	ISO 8859-14	Celtic	Yes	1	ISO885914
LATIN9	ISO 8859-15	LATIN1 with Euro and accents	Yes	1	ISO885915
LATIN10	ISO 8859-16, ASRO SR 14111	Romanian	Yes	1	ISO885916
MULE_INTERNAL	Mule internal code	Multilingual Emacs	Yes	1-4	
SJIS	Shift JIS	Japanese	No	1-2	Mskanji, ShiftJIS, WIN932, Windows932
SQL_ASCII	unspecified [^2]	any	No	1	
UHC	Unified Hangul Code	Korean	No	1-2	WIN949, Windows949
UTF8	Unicode, 8-bit	all	Yes	1-4	Unicode
WIN866	Windows CP866	Cyrillic	Yes	1	ALT
WIN874	Windows CP874	Thai	Yes	1	
WIN1250	Windows CP1250	Central European	Yes	1	
WIN1251	Windows CP1251	Cyrillic	Yes	1	WIN
WIN1252	Windows CP1252	Western European	Yes	1	
WIN1253	Windows CP1253	Greek	Yes	1	
WIN1254	Windows CP1254	Turkish	Yes	1	
WIN1255	Windows CP1255	Hebrew	Yes	1	
WIN1256	Windows CP1256	Arabic	Yes	1	
WIN1257	Windows CP1257	Baltic	Yes	1	
WIN1258	Windows CP1258	Vietnamese	Yes	1	ABC, TCVN, TCVN5712, VSCII

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Setting the Character Set

gpinitsystem defines the default character set for a WarehousePG cluster by reading the setting of the `ENCODING` parameter in the `gp_init_config` file at initialization time. The default character set is `UNICODE` or `UTF8`.

You can create a database with a different character set besides what is used as the system-wide default. For example:

```
=> CREATE DATABASE korean WITH ENCODING 'EUC_KR';
```

> **Important** Although you can specify any encoding you want for a database, it is unwise to choose an encoding that is not what is expected by the locale you have selected. The `LC_COLLATE` and `LC_CTYPE` settings imply a particular encoding, and locale-dependent operations (such as sorting) are likely to misinterpret data that is in an incompatible encoding.

Since these locale settings are frozen by gpinitsystem, the apparent flexibility to use different encodings in different databases is more theoretical than real.

One way to use multiple encodings safely is to set the locale to `C` or `POSIX` during initialization time, thus deactivating any real locale awareness.

Character Set Conversion Between Server and Client

WarehousePG supports automatic character set conversion between server and client for certain character set combinations. The conversion information is stored in the coordinator `pg_conversion` system catalog table. WarehousePG comes with some predefined conversions or you can create a new conversion using the SQL command `CREATE CONVERSION`.

Server Character Set	Available Client Character Sets
BIG5	not supported as a server encoding
EUC_CN	EUC_CN, MULE_INTERNAL, UTF8
EUC_JP	EUC_JP, MULE_INTERNAL, SJIS, UTF8
EUC_KR	EUC_KR, MULE_INTERNAL, UTF8
EUC_TW	EUC_TW, BIG5, MULE_INTERNAL, UTF8
GB18030	not supported as a server encoding
GBK	not supported as a server encoding
ISO_8859_5	ISO_8859_5, KOI8, MULE_INTERNAL, UTF8, WIN866, WIN1251
ISO_8859_6	ISO_8859_6, UTF8
ISO_8859_7	ISO_8859_7, UTF8
ISO_8859_8	ISO_8859_8, UTF8
JOHAB	JOHAB, UTF8
KOI8	KOI8, ISO_8859_5, MULE_INTERNAL, UTF8, WIN866, WIN1251
LATIN1	LATIN1, MULE_INTERNAL, UTF8
LATIN2	LATIN2, MULE_INTERNAL, UTF8, WIN1250
LATIN3	LATIN3, MULE_INTERNAL, UTF8
LATIN4	LATIN4, MULE_INTERNAL, UTF8
LATIN5	LATIN5, UTF8
LATIN6	LATIN6, UTF8
LATIN7	LATIN7, UTF8
LATIN8	LATIN8, UTF8
LATIN9	LATIN9, UTF8
LATIN10	LATIN10, UTF8
MULE_INTERNAL	MULE_INTERNAL, BIG5, EUC_CN, EUC_JP, EUC_KR, EUC_TW, ISO_8859_5, KOI8, LATIN1 to LATIN4, SJIS, WIN866, WIN1250, WIN1251
SJIS	not supported as a server encoding
SQL_ASCII	not supported as a server encoding
UHC	not supported as a server encoding
UTF8	all supported encodings
WIN866	WIN866
ISO_8859_5	KOI8, MULE_INTERNAL, UTF8, WIN1251
WIN874	WIN874, UTF8
WIN1250	WIN1250, LATIN2, MULE_INTERNAL, UTF8
WIN1251	WIN1251, ISO_8859_5, KOI8, MULE_INTERNAL, UTF8, WIN866
WIN1252	WIN1252, UTF8
WIN1253	WIN1253, UTF8
WIN1254	WIN1254, UTF8
WIN1255	WIN1255, UTF8
WIN1256	WIN1256, UTF8
WIN1257	WIN1257, UTF8
WIN1258	WIN1258, UTF8

To enable automatic character set conversion, you have to tell WarehousePG the character set (encoding) you would like to use in the client. There are several ways to accomplish this:

- Using the `\encoding` command in `psql`, which allows you to change client encoding on the fly.

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- Using `SET client_encoding TO`. Setting the client encoding can be done with this SQL command:

  ```
  => SET CLIENT_ENCODING TO '<value>';
  ```

  To query the current client encoding:

  ```
  => SHOW client_encoding;
  ```

  To return to the default encoding:

  ```
  => RESET client_encoding;
  ```

- Using the `PGCLIENTENCODING` environment variable. When `PGCLIENTENCODING` is defined in the client's environment, that client encoding is automatically selected when a connection to the server is made. (This can subsequently be overridden using any of the other methods mentioned above.)

- Setting the configuration parameter `client_encoding`. If `client_encoding` is set in the coordinator `postgresql.conf` file, that client encoding is automatically selected when a connection to WarehousePG is made. (This can subsequently be overridden using any of the other methods mentioned above.)

If the conversion of a particular character is not possible — suppose you chose `EUC_JP` for the server and `LATIN1` for the client, then some Japanese characters do not have a representation in `LATIN1` — then an error is reported.

If the client character set is defined as `SQL_ASCII`, encoding conversion is deactivated, regardless of the server's character set. The use of `SQL_ASCII` is unwise unless you are working with all-ASCII data. `SQL_ASCII` is not supported as a server encoding.

[^1]: Not all APIs support all the listed character sets. For example, the JDBC driver does not support MULE_INTERNAL, LATIN6, LATIN8, and LATIN10.

[^2]: The SQL_ASCII setting behaves considerably differently from the other settings. Byte values 0-127 are interpreted according to the ASCII standard, while byte values 128-255 are taken as uninterpreted characters. If you are working with any non-ASCII data, it is unwise to use the SQL_ASCII setting as a client encoding. SQL_ASCII is not supported as a server encoding.

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3.11 Important Changes Between WHPG 6 and WHPG 7

There are a substantial number of changes between WarehousePG 6 and WarehousePG 7 that could potentially affect your existing 6 application when you move to 7. This topic provides information about these changes.

Naming Changes

The following table summarizes naming changes in WarehousePG 7:

Old Name	New Name
master	coordinator
pg_log	log
pg_xlog	pg_wal
pg_clog	pg_xact
xlog (includes SQL functions, tools and options)	wal
pg_xlogdump	pg_waldump
pg_resetxlog	pg_resetwal

Deprecated Features

The following features have been deprecated in WarehousePG 7:

- The `gpreload` utility. Instead, use `ALTER TABLE...REPACK BY`.

Changes in Feature Behavior

The following feature behaviors have changed in WarehousePG 7:

- The `checkpoint_segments` parameter in the `postgresql.conf` file has been removed. Use the server configuration parameters `min_wal_size` and `max_wal_size`, instead.
- Autovacuum is now enabled by default for all databases.
- Pattern matching behavior of the `substring()` function has changed. In cases where the pattern can be matched in more than one way, the initial subpattern is now treated as matching the least possible amount of text rather than the greatest; for example, a pattern such as `%#"aa*#"%` now selects the first group of `a`'s from the input, rather than the last group.
- Multi-dimensional arrays can now be passed into PL/Python functions, and returned as nested Python lists - Previously, you could return an array of composite values by writing, for exmaple, `[[col1, col2], [col1, col2]]`. Now, this is interpreted as a two-dimensional array. Composite types in arrays must now be written as Python tuples, not lists, to resolve the ambiguity; that is, you must write `[(col1, col2), (col1, col2)]`, instead.
- When `x` is a table name or composite column, PostgreSQL has traditionally considered the syntactic forms `f(x)` and `x.f` to be equivalent, allowing tricks such as writing a function and then using it as though it were a computed-on-demand column. However, if both interpretations are feasible, the column interpretation was always chosen. Now, if there is ambiguity, the interpretation that matches the syntactic form is chosen.
- WarehousePG 7 now prevents the `to_number()` function from consuming characters when the template separator does not match. For example, `SELECT to_number('1234', '9,999')` used to return `134`. It will now return `1234`, instead. L and TH now only consume characters that are not digits, positive/negative signs, decimal points, or commas.
- The `fix to_date()`, `to_number()`, and `to_timestamp()` functions previously skipped one byte for each byte of template character, resulting in strange behavior if either string contained multibyte characters. Adjust the handling of backslashes inside double-quotes in template strings for to_char(), to_number(), and to_timestamp(). Such a backslash now escapes the character after it, particularly a double-quote or another backslash.

Other Important Changes in WarehousePG 7

WarehousePG 7 also:

- Removes some features and objects that were in Greeplum 6. See Features and Objects Removed in WarehousePG 7.
- Changes some server configuration parameters. See Server Configuration Parameter Changes from WarehousePG 6 to WarehousePG 7.
- Changes the partitioning system catalogs. See Changes in Partitioning and Migrating Partition Maintenance Scripts to the New WarehousePG 7 Partitioning Catalogs.
- Makes changes to external tables. See Changes to External Tables.
- Makes changes to resource groups. See Changes to Resource Groups.
- Makes changes to system views and system tables. See System Catalog Changes between WarehousePG 6 and WarehousePG 7.

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3.12 Performing a minor upgrade

Perform a minor version upgrade to 7.4. Because minor versions are binary-compatible, this process replaces the software binaries without requiring a full data migration.

An upgrade involves stopping the WHPG cluster, updating the software binaries across all nodes, and restarting the services.

> **Note**
>
> Starting from WarehousePG 7.4, the installation directory has been consolidated to `/usr/edb/whpg7`. For backward compatibility, the system automatically maintains a symbolic link at `/usr/local/greenplum-db` and `/usr/local/greenplum-db-clients`.

In this guide:

- `7.origin` refers to your current version.
- `7.target` refers to the version you are upgrading to.

Process overview

The following high-level steps summarize the upgrade lifecycle:

1. Prepare for maintenance: Isolate the cluster and secure a full backup.
2. Clear automation: Disable scheduled tasks and coordinate infrastructure snapshots.
3. Validate baseline: Verify current software versions and run smoke tests.
4. Quiesce the database: Stop peripheral services and the WHPG cluster.
5. Replace binaries: Install the new software package across all cluster nodes.
6. Restore services: Restart the cluster and verify health.
7. Re-establish connectivity: Restore automation, connection pooling, and federation.
8. Hand back: Resume normal business operations and monitoring.

Preparing for maintenance

These steps isolate the cluster from external traffic and automated scripts before the system handover.

1. Stop all monitoring applications: Shut down all monitoring agents to prevent false alerts during the maintenance window.

2. Stop scheduled tasks: Disable external schedulers that trigger jobs against the database.

3. Stop applications: Notify users and shut down application servers, web services, and BI tools. Ensure no new connections are being initiated.

4. Perform a backup of all databases: Execute a full backup. This is your final safety point before modifying the environment.

   ```
   gpbackup --leaf-partition-data
   ```

Clearing automation and system handover

Once data is secure and traffic has ceased, prepare the operating system environment.

1. Hand over the for infrastructure maintenance: Coordinate with your Infrastructure or Platform team to perform any required pre-upgrade safety measures. This may include creating environment snapshots, initiating virtual machine checkpoints, or performing hardware-level health checks to ensure the underlying platform is stable.

2. Save and remove crontab entries: Perform these steps as the `root` user on coordinator and standby nodes to prevent maintenance scripts from firing during the binary swap.

   - Back up your `gpadmin` tasks from both the coordinator and standby nodes:

     ```
     crontab -l -u gpadmin > /home/gpadmin/crontab_backup_$(date +%F)
     ```

   - Check for other user crontabs:

     ```
     crontab -u <username> -
     l
     for user in $(cut -f1 -d: /etc/passwd); do echo $user; crontab -u $user -l; done >crontab_all
     2>crontab_all_no_cron
     ```

   - Remove current entries:

     ```
     crontab -r
     ```

   - Verify the list is empty (should return `no crontab for gpadmin`):

     ```
     crontab -l
     ```

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Establishing a pre-upgrade baseline

Before beginning the update, capture the current state of your environment. This baseline serves as a reference point to ensure that all software versions, configurations, and connectivity are restored correctly once the update is complete.

1. Inventory installed packages: Document the exact versions of the WHPG packages currently running on the coordinator and segments.
    - For RHEL 8, RHEL 9: `sudo rpm -qa | grep whpg`
    - For RHEL 7: `sudo yum list installed | grep whpg`
2. Record component versions: Document the versions of any additionally installed components, such as PXF, or PgBouncer. For example:
    - Check PXF version: `pxf --version`
    - Check pgBouncer version: Connect to the admin console with `psql -p 6543 -U pgbouncer -d pgbouncer` and run `SHOW VERSION;`.
3. Perform a PXF smoke test: Ensure pre-upgrade connectivity is functional to confirm any connectivity issues found after the upgrade were not pre-existing. For example:

```
psql -x demo -c 'SELECT * FROM public.jsonb_events LIMIT
2;'
```

Quiescing the database

Perform a final cleanup of the running database instance.

1. Stop exernal services: Shut down the PXF service on all nodes and stop the PgBouncer connection pooler.
    - Stop PXF: `pxf cluster stop`
    - Stop pgBouncer: Connect to the admin console with `psql -p 6543 -U pgbouncer -d pgbouncer` and run `SHUTDOWN;`.
2. Terminate sessions and check queries: Ensure no active user queries remain. Forcefully terminate any remaining client backends.

```
# View active
queries
psql -d postgres -c "SELECT * FROM pg_stat_activity where backend_type = 'client backend' and state <>
'idle';"
# Terminate a specific
PID
psql -d postgres -c 'SELECT
pg_cancel_backend(<procpid>);'
```

3. Verify segment health: Run `gpstate -m`. All segments must be in `Synchronized` status. If not, run `gprecoverseg -a` and wait for completion.
4. Stop the WHPG cluster:

```
gpstop -a -M fast
```

Replacing binaries and restarting WHPG

Perform the following steps as the `gpadmin` user. When upgrading, the package manager will automatically remove old files in `/usr/local/greenplum-db-<version>` and install new files to `/usr/edb/whpg7`.

1. On the coordinator, back up old WHPG binaries:

```
sudo cp -R /usr/local/greenplum-db-7.origin-WHPG /usr/local/greenplum-db-7.origin-
WHPG_save
sudo chown -R gpadmin /usr/local/greenplum-db-7.origin-
WHPG_save
```

2. Download your `7.target` package. See Downloading the WarehousePG Server Software for details on how to download the packages. From your jump host, copy the new package to the coordinator:

```
scp <warehouse-pg-7.target.rpm>
gpadmin@coordinator_host:/tmp
scp <warehouse-pg-7.target-clients.rpm>
gpadmin@coordinator_host:/tmp
```

   Where `<warehouse-pg-7.target.rpm>` is the package of the WarehousePG version to install.

3. On the coordinator, create a file `hostfile_without_coord` that lists all hosts in the cluster except the coordinator. For example:

```
scdw
sdw1
sdw2
sdw3
```

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4. From the coordinator, create a directory for the binaries on all hosts and transfer the new package:

```
gpssh -f hostfile_without_coord -e "mkdir -p
/tmp/binary"
gpsync -f hostfile_without_coord <warehouse-pg-7.target.rpm> =:/tmp/binary
```

5. Install WHPG `7.target` on the coordinator:

> **Important**
>
> Starting with WarehousePG 7.4, the `warehouse-pg-7-clients` package is mandatory and must be installed alongside the server package.

   - For RHEL 8, RHEL 9:

```
sudo rpm -U <warehouse-pg-7.target.rpm> -
v
sudo chown -R gpadmin.
/usr/edb/whpg7
```

   - For RHEL 7:

```
sudo yum install -y <warehouse-pg-
7.target.rpm>
sudo chown -R gpadmin.
/usr/edb/whpg7
```

6. Install WHPG `7.target` on segments: From the coordinator, run:

   - For RHEL 8, RHEL 9:

```
source
/home/gpadmin/.bashrc
gpssh -f hostfile_without_coord -e "sudo rpm -U <warehouse-pg-7.target.rpm> -v"
gpssh -f hostfile_without_coord -e "sudo chown -R gpadmin:gpadmin
/usr/edb/whpg7"
```

   - For RHEL 7:

```
source
/home/gpadmin/.bashrc
gpssh -f hostfile_without_coord -e "sudo yum install -y <warehouse-pg-7.target.rpm>"
gpssh -f hostfile_without_coord -e "sudo chown -R gpadmin:gpadmin /usr/edb/whpg7"
```

7. Verify symbolic links: Ensure `/usr/local/greenplum-db` and `/usr/local/greenplum-db-clients` point to `/usr/edb/whpg7` across the cluster and that `gpadmin` is the owner of the installation directories:

```
ll /usr/local/'| grep 'greenplum-db ->' |
sort
gpssh -f hostfile_without_coord  -e "ll /usr/local/'| grep 'greenplum-db ->' |
sort"
```

Restoring services and finalizing the upgrade

Start the WHPG cluster on the target version. After the cluster is back online, restart the extension services and restore the operational environment.

1. Update environment: Ensure `/home/gpadmin/.bashrc` on coordinator and standby points to the new path, then reload:

```
source
/home/gpadmin/.bashrc
```

2. Start WHPG:

```
gpstart -a
```

3. Perform system health check: Run `gpstate -f` and `gpstate -m` to ensure all segments are up and mirrors are synchronized.

4. Verify the installed version:

```
psql -d postgres -c "select
version();"
psql -d postgres -c "select distinct  version() from
gp_dist_random('gp_id');"
```

Restoring automation and connectivity

Once the core database services are back online, re-establish the secondary layers to return the cluster to a full operational state.

1. Restore crontabs: Reload the saved files for `gpadmin` on coordinator and standby hosts. For example:

```
crontab -u gpadmin /home/gpadmin/crontab_backup_YYYY-MM-
DD
```

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2. Start PXF and re-run the smoke test query:

```
pxf cluster start
psql -x demo -c 'SELECT * FROM public.jsonb_events LIMIT
2;'
```

3. Start PgBouncer: Restart the connection pooler and verify client connections.

```
pgbouncer -d /data/gpdata/pgbouncer/pgbouncer.ini
psql -p 6543 -U pgbouncer -d pgbouncer -c "SHOW CLIENTS;"
```

Handing back the system

With the upgrade verified and the infrastructure services restored, the final phase involves transitioning the environment back to the end-users and resuming normal business operations.

1. Applications: Re-enable application traffic and BI tools.
2. Schedules: Re-enable external schedulers.
3. Monitoring: Resume all monitoring agents.
4. Handover: Formally notify the Infrastructure or Platform teams that the cluster is stable on version `7.target`.

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3.13 Upgrading from WarehousePG 6 to WarehousePG 7

This topic walks you through upgrading from WarehousePG 6 to WarehousePG 7.

> **WARNING** There are a substantial number of changes between WarehousePG 6 and WarehousePG 7 that could potentially affect your existing application when you move to WarehousePG 7. Before going any further, familiarize yourself with all of these changes Important Changes between WHPG 6 and WHPG 7 .

> **Note** You cannot upgrade to WarehousePG 7.0.0 using the `gpupgrade` utility.

Preparing to Upgrade

To prepare for upgrading from WarehousePG 6 to WarehousePG 7:

- Read carefully through Important Changes between WHPG 6 and WHPG 7 to identify changes you may need to make in your application before upgrading to WarehousePG 7.
- Before using `gpbackup` / `gprestore` to move your data, read carefully through Backup and Restore Caveats to avert problems that can arise.

Steps to Upgrade

Follow the steps in this section to upgrade from WarehousePG 6 to WarehousePG 7.

When upgrading, the `gpbackup/gprestore` utilities are the recomended tools for data loading.

Steps to Upgrade Using Backup/Restore

Review Backup and Restore Caveats before starting the upgrade.

To upgrade while moving data using `gpbackup/gprestore` :

1. If not already installed, install the latest release of the WarehousePG Backup and Restore utilities
2. Run the `gpbackup` utility to back up the data from your WarehousePG 6 cluster to an external data storage location, such as mounted directories, cloud storage, or Data Domain.
3. Initalize a WarehousePG 7 cluster on the destination hardware, by issuing the `gpinitsystem` command.
4. Install any external modules used in your WarehousePG 6 system in the WarehousePG 7 system before you restore the backup, for example MADlib or PostGIS. If versions of the external modules are not compatible, you may need to exclude tables that reference them when restoring the WarehousePG 6 backup to WarehousePG 7.
5. Run the `gprestore` utility to restore your data to the WarehousePG 7 cluster from the external data storage location.

Completing the Upgrade

Migrate any tables you skipped during the restore using other methods, for example using the `COPY TO` command to create an external file and then loading the data from the external file into WarehousePG 6 with the `COPY FROM` command.

Recreate any objects you dropped in the WarehousePG 6 database to enable migration, such as external tables, indexes, user-defined functions, or user-defined aggregates.

After migrating data you may need to modify SQL scripts, administration scripts, and user-defined functions as necessary to account for changes in WarehousePG version 7. Review the WarehousePG Release Notes and Important Changes between WHPG 6 and WHPG 7 for features and changes that may necessitate post-migration tasks.

Backup and Restore Caveats

There are a number of caveats with respect to backing up and restoring your data as part of upgrading from WarehousePG 6 to WarehousePG 7.

- Before you do an actual backup, use `gpbackup` to create a `--metadata-only` backup from the source WarehousePG and restore it to the WarehousePG 7 system. Review the `gprestore` log file for error messages and correct any remaining problems in the source WarehousePG.
- If you intend to install WarehousePG 7 on the same hardware as your 6 system, you will need enough disk space to accommodate over five times the original data set (two full copies of the primary and mirror data sets, plus the original backup data in ASCII format) in order to migrate data with `gpbackup` and `gprestore` . Keep in mind that the ASCII backup data will require more disk space than the original data, which may be stored in compressed binary format. Offline backup solutions such as Dell PowerProtect (Data Domain) can reduce the required disk space on each host.

  If you do not have the disk space, then:

  - Run `gpbackup` on your WarehousePG 6 cluster to back up your data
  - Run `gpdeletesystem` to remove the existing WarehousePG 6 cluster
  - Proceed with initializing the new cluster, as described above
- When restoring language-based user-defined functions, the shared object file must be in the location specified in the `CREATE FUNCTION` SQL command and must have been recompiled on the WarehousePG 7 system. This applies to user-defined functions, user-defined types, and any other objects that use custom functions, such as aggregates created with the `CREATE AGGREGATE` command.
- `gpbackup` saves the distribution policy and distribution key for each table in the backup so that data can be restored to the same segment. If a table's distribution key in the WarehousePG 6 database is incompatible with WarehousePG 7, `gprestore` cannot restore the table to the correct segment in the WarehousePG 6 database. This can happen if the distribution key in the older WarehousePG release has columns with data types not allowed in WarehousePG 7 distribution keys, or if the data representation for data types has changed or is insufficient for WarehousePG 7 to generate the same hash value for a distribution key. You should correct these kinds of problems by altering distribution keys in the tables before you back up the WarehousePG.

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Parent topic: Installing and Upgrading WarehousePG

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3.14 >-

This topic provides guidance on migrating partition maintenance scripts that you may have written for WarehousePG 6 to use the new partitioning system catalogs in WarehousePG 7.

About the WarehousePG 6 and 7 Partitioning Catalogs

The following partitioning-related catalog tables, views, and functions available in WarehousePG 6 are removed in WarehousePG 7:

- `pg_partition`
- `pg_partition_columns`
- `pg_partition_encoding`
- `pg_partition_rule`
- `pg_partition_templates`
- `pg_partitions`
- `pg_stat_partition_operations`
- `pg_partition_def()`

WarehousePG 7 adds the following new catalog table and functions:

- gp_partition_template
- pg_partitioned_table
- pg_partition_tree()
- pg_partition_ancestors()
- pg_partition_root()

Why are Migration Tasks Required?

Because partitioning-related system catalog, view, and function definitions have changed in WarehousePG 7, you must update any partition maintenance scripts that you have been using in WarehousePG 6.

The following sections identify, for each WarehousePG 6 partitioning catalog column, how to obtain similar information in WarehousePG 7. These mappings should help ease your partition maintenance migration effort.

In some cases, there is an equivalent field in, or query of, a WarehousePG 7 system catalog or view. In other cases, there may be no direct mapping because WarehousePG 7 no longer stores the information in the catalog.

pg_partitions

The WarehousePG 6 `pg_partitions` view displays all leaf partitions in the current database.

Column Name	WarehousePG 6 Description	WarehousePG 7 Equivalent
schemaname	The name of the schema in which the root partitioned table resides.	Use `pg_partition_root()` to obtain the root object identifier, and then query pg_namespace.
tablename	The name of the root partitioned table.	Use `pg_partition_root()` to obtain the root object identifier, and then query pg_class.
partitionschemaname	The namespace of the leaf partition.	pg_namespace
partitiontablename	The table name of the leaf partition (the table name you use to access the partition directly).	pg_class
partitionname	The partition name of the leaf partition (the name you use to refer to the partition in an `ALTER TABLE` command).	N/A
parentpartitiontablename	The table name of the parent table of this partition.	Get the parent object identifier via pg_inherits and then query pg_class.
parentpartitionname	The partition name of the parent table of this partition.	N/A
partitiontype	The type of partition (range or list).	Get the parent object identifier via pg_inherits and then query pg_partitioned_table.
partitionlevel	The level of this partition in the partition hierarchy.	Get the level from `pg_partition_tree()` using the root object identifier. Note that the level differs in WarehousePG 6 and 7. In WarehousePG 6, the level of the immediate child of a partitioned table is 0. In WarehousePG 7, the level of the partitioned table itself is 0, and the level of its immediate child is 1.
partitionrank	For range partitions, the rank of the partition compared to other partitions at the same level.	N/A
partitionposition	The rule order position of this partition.	N/A
partitionlistvalues	For list partitions, the list value(s) associated with this partition.	Get the partition boundary via `pg_get_expr()` and then filter the text.
partitionrangestart	For range partitions, the start value of this partition.	Get the partition boundary via `pg_get_expr()` and then filter the text.
partitionstartinclusive	Whether or not the start value is included in this partition. `true` if the start value is included.	always inclusive
partitionrangeend	For range partitions, the end value of this partition.	Get the partition boundary via `pg_get_expr()` and then filter the text.
partitionendinclusive	Whether or not the end value is included in this partition. `true` if the end value is included.	always exclusive
partitioneveryclause	The `EVERY` clause (interval) of this partition.	N/A
partitionisdefault	Whether or not this is a default partition. `true` if this is the default, otherwise `false`.	Get the partition boundary via `pg_get_expr()` and check if it is `DEFAULT`. Alternatively, use `pg_partitioned_table.partdefid`.
partitionboundary	The entire partition specification for this partition.	`pg_get_expr()`, but note that it is returned in modern syntax.
parenttablespace	The tablespace of the parent table of this partition.	Get the parent object identifier via pg_inherits and then query pg_tablespace.
partitiontablespace	The tablespace of this partition.	pg_tablespace

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Examples Retrieving Similar Information in WarehousePG 7

Some of the information is quite trivial to retrieve in WarehousePG 7, while other information is not. The following sections provide examples for specific WarehousePG 6 system catalog columns.

partitionname / parentpartitionname

The `partitionname` and `parentpartitionname` columns provide the WarehousePG 6 "partition name" in constrast to the actual table name. Because WarehousePG 7 no longer stores the partition name in the catalog (previously in `pg_partition_rule`), it cannot retrieve that information now. Use the table names directly to refer to the partitions. However, if you really need the partition name, you can achieve that via some text massaging:

```
SELECT
    c.relname AS table_name,
    split_part(substr(c.relname, position(inh.inhparent::regclass::text in c.relname) + length(inh.inhparent::regclass::text)), '_', 4) AS partition_name
FROM
    pg_class c
LEFT JOIN
    pg_inherits inh ON inh.inhrelid = c.oid
WHERE
    c.relname LIKE concat(inh.inhparent::regclass::text, '%')
    AND c.relname LIKE '<your_partition_name>';
```

This query is valid only if the table name is implicitly generated by WarehousePG from the partition name and is in the form of `<parent_tablename>_prt_<level>_<partition_name>`. This query will not work for a partitioned table created with modern syntax (where you always specify the table name when adding a partition) or for a partitioned table created with classic syntax where you explicitly specify the table name in a `WITH` clause for the partition.

partitionposition / partitionrank

The `partitionposition` and `partitionrank` columns in the WarehousePG 6 `pg_partitions` view are based on the "order" number for each partition in the `pg_partition_rule` catalog, but that catalog is removed in WarehousePG 7. However, if you are simply interested in retrieving the sorted order for range partitions, you can order the range value. For example, if the WarehousePG 6 query below provides the highest rank partition:

```
SELECT
    CASE
        WHEN partitionstartinclusive THEN partitionrangestart
        ELSE partitionrangeend
    END AS old_part_value
FROM
    pg_catalog.pg_partitions p
WHERE
    p.schemaname = '" + cfg.schema + "'
    AND p.tablename = '" + cfg.table + "'
    AND p.partitiontype = 'range'
    AND p.partitionlevel = " + str(cfg.partition_level) + "
    AND " + chk + "
ORDER BY
    partitionrank
LIMIT 1;
```

A similar query in WarehousePG 7 follows:

```
SELECT
   rank() OVER (
       PARTITION BY pc.oid
       ORDER BY CAST(
           (regexp_matches(pg_get_expr(c.relpartbound, c.oid), 'FOR VALUES FROM \(([0-9]+)\) TO \(([0-9]+)\)'))[1]
           AS INTEGER
       )
   ) AS rank,
    (regexp_matches(pg_get_expr(c.relpartbound, c.oid), 'FOR VALUES FROM \(([0-9]+)\) TO \(([0-9]+)\)'))[1] AS old_part_value
FROM
    pg_class c
LEFT JOIN
    pg_inherits inh ON inh.inhrelid = c.oid
LEFT JOIN
    pg_partitioned_table pt ON inh.inhparent = pt.partrelid
LEFT JOIN
    pg_class pc ON pc.oid = pt.partrelid
WHERE
    c.relispartition = 't' AND pc.relname LIKE ('<partition_root_schema>.<partition_root_name>')
ORDER BY
    rank
LIMIT 1;
```

Assuming that the partitioning method for the partitioned table is `RANGE`, the above query calculates the ranks for each child partition, and prints the range `START` value (which is always inclusive) with the highest rank.

You cannot retrieve the order number for list partitions with this query, however, because the order is based on the time the partition is added, and WarehousePG 7 does not store that information. A query for list partitions must not be dependent on order information.

partitioneveryclause

Because WarehousePG 7 does not store the use of the `EVERY` clause in the catalog, it can not discern if a partition was created with the clause. The main use of this column is to reconstruct a partition definition clause using the classic-syntax for display or `pg_dump` purposes. No mapping is provided at this time.

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partitionstartinclusive / partitionendinclusive

WarehousePG 7 supports the classic syntax `INCLUSIVE` and `EXCLUSIVE` clauses through the adjustment of `START` and `END` values. It dos not record whether a range `START` or `END` is inclusive or not, because the `START` is always inclusive and the `END` is always exclusive. So the `partitionstartinclusive` and `partitionendinclusive` columns are simply redundant.

partitionboundary

You can retrieve the partition boundary definition in WarehousePG 7 via the `pg_get_expr()` function:

```
SELECT
    pg_get_expr(relpartbound, oid)
FROM
    pg_class
WHERE
    relispartition = 't';
```

Composing a Similar View in WarehousePG 7

An approximate `pg_partitions` view follows. This view, given all limitations addressed above, prints the information that is possible to retrieve in WarehousePG 7.

> **Caution** This example is for illustrative purposes only, not for practical use.

```
SELECT
    (SELECT relnamespace::regnamespace FROM pg_class WHERE oid = pg_partition_root(c.oid)) AS schemaname,
    (SELECT pg_partition_root(c.oid)::regclass) AS tablename,
    n.nspname AS partitionschemaname,
    c.relname AS partitiontablename,
    -- assuming the table name is implicitly generated like <parent>_prt_<id>_<partition>
    split_part(
        substr(c.relname, position(pc.relname in c.relname) + length(pc.relname)),
        '_',
        4
    ) AS partitionname,
    pc.relname AS parentpartitiontablename,
    -- same assumption as above
    split_part(
        substr(pc.relname, position(ppc.relname in pc.relname) + length(ppc.relname)),
        '_',
        4
    ) AS parentpartitionname,
    CASE
        WHEN pt.partstrat = 'r' THEN 'range'
        ELSE 'list'
    END AS partitiontype,
    (SELECT level FROM pg_partition_tree(pg_partition_root(c.oid)) WHERE relid = c.oid) AS partitionlevel,
    -- can be calculated like a previous example
    NULL AS partitionrank,
    -- cannot be trusted because no real order for list partitions
    NULL AS partitionposition,
    (regexp_matches(pg_get_expr(c.relpartbound, c.oid), 'FOR VALUES IN \(\((.*?)\)'))[1] AS partitionlistvalues,
    -- assuming range values are normal integers instead of expressions which WarehousePG 7 supports
    (regexp_matches(pg_get_expr(c.relpartbound, c.oid), 'FOR VALUES FROM \(\([0-9]+)\) TO \(\([0-9]+)\)'))[1] AS partitionrangestart,
    't' AS partitionstartinclusive,
    (regexp_matches(pg_get_expr(c.relpartbound, c.oid), 'FOR VALUES FROM \(\([0-9]+)\) TO \(\([0-9]+)\)'))[2] AS partitionrangeend,
    'f' AS partitionendinclusive,
    -- information cannot be retrieved
    NULL AS partitioneveryclause,
    CASE
        WHEN pg_get_expr(c.relpartbound, c.oid) = 'DEFAULT' THEN 't'
        ELSE 'f'
    END AS partitionisdefault,
    (regexp_matches(pg_get_expr(c.relpartbound, c.oid), '.+'))[1] AS partitionboundary,
    CASE
        WHEN pc.reltablespace = 0 THEN 'pg_default'
        ELSE (SELECT spcname FROM pg_tablespace WHERE oid = pc.reltablespace)
    END AS parenttablespace,
    CASE
        WHEN c.reltablespace = 0 THEN 'pg_default'
        ELSE (SELECT spcname FROM pg_tablespace WHERE oid = c.reltablespace)
    END AS partitiontablespace
FROM
    pg_class c
LEFT JOIN
    pg_namespace n ON n.oid = c.relnamespace
LEFT JOIN
    pg_inherits inh ON inh.inhrelid = c.oid
LEFT JOIN
    pg_partitioned_table pt ON inh.inhparent = pt.partrelid
LEFT JOIN
    pg_class pc ON pc.oid = pt.partrelid
LEFT JOIN
    pg_inherits pinh ON pinh.inhrelid = pc.oid
LEFT JOIN
    pg_partitioned_table ppt ON pinh.inhparent = ppt.partrelid
LEFT JOIN
    pg_class ppc ON ppc.oid = ppt.partrelid
WHERE
    c.relispartition = 't';
```

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pg_partition_columns

The WarehousePG 6 `pg_partition_columns` view displays the partition key columns of a partitioned table.

Column Name	WarehousePG 6 Description	WarehousePG 7 Equivalent
schemaname	The name of the schema in which the partitioned table resides.	Get the root partitioned table object identifier via `pg_partition_root()` and then query pg_namespace.
tablename	The table name of the partitioned table.	pg_class
columnname	The name of the partition key column.	pg_attribute
partitionlevel	The level of this subpartition in the partition hierarchy.	Get the level from `pg_partition_tree()` using the parent object identifier.
position_in_partition_key	List partitions can have a composite (multi-column) partition key. This attribute identifies the position of the column in a composite key.	always 1

The `position_in_partition_key` column is no longer relevant in WarehousePG 7. WarehousePG 7 supports a multi-column partition key via multi-column type, so the relative position of the column in the partition key will always be one. Another reason that this no longer holds true in WarehousePG 7: the `pg_partition_columnns` view assumes a homogenous partition structure, while WarehousePG 7 also supports heterogenous partition structures.

Composing a Similar View in WarehousePG 7

As long as these two assumptions hold:

1. The partitioned table does not have a multi-column partition key.
2. All partition structures are a homogeneous.

A query to generate a comparable view in WarehousePG 7 follows:

```
SELECT
    c.relnamespace::regnamespace AS schemaname,
    c.relname AS tablename,
    att.attname AS columnname,
    (
        SELECT level
        FROM pg_partition_tree(pg_partition_root(c.oid))
        WHERE relid = c.oid
    ) AS partitionlevel,
    1 AS position_in_partition_key
FROM
    pg_partitioned_table pt
LEFT JOIN
    pg_class c ON c.oid = pt.partrelid
JOIN
    pg_attribute att ON c.oid = att.attrelid AND att.attnum = pt.partattrs[0];
```

pg_partition_rule

The WarehousePG 6 `pg_partition_rule` table tracks partitioned tables, their check constraints, and their data containment rules.

Column Name	WarehousePG 6 Description	WarehousePG 7 Equivalent
paroid	The row identifier of the partitioning level (from `pg_partition`) to which this partition belongs. In the case of a branch partition, the corresponding table (identified by `pg_partition_rule`) is an empty container table. In the case of a leaf partition, the table contains the rows for that partition containment rule.	N/A (removed object)
parchildrelid	The table identifier of the partition.	pg_class
parparentrule	The row identifier of the rule associated with the parent table of this partition.	N/A (removed object)
parname	The given name of this partition.	pg_class
parisdefault	Specifies whether or not this partition is a default partition.	See pg_partitions.partitionisdefault.
parruleord	For range partitioned tables, the rank of this partition in this level of the partition hierarchy.	N/A (See the explanation for the `partitionposition` / `partitionrank` columns in pg_partitions.)
parrangestartincl	For range partitioned tables, specifies whether or not the starting value is inclusive.	always inclusive
parrangeendincl	For range partitioned tables, specifies whether or not the ending value is inclusive.	always exclusive
parrangestart	For range partitioned tables, the starting value of the range.	See pg_partitions.partitionrangestart.
parrangeend	For range partitioned tables, the ending value of the range.	See pg_partitions.partitionrangeend.
parrangeevery	For range partitioned tables, the interval value of the `EVERY` clause.	N/A (See pg_partitions.partitioneveryclause.)
parlistvalues	For list partitioned tables, the list of values assigned to this partition.	See pg_partitions.partitionlistvalues.
parreloptions	An array describing the storage characteristics of the particular partition.	pg_class.reloptions

pg_partition

The WarehousePG 6 `pg_partition` system catalog table tracks partitioned tables and their inheritance level relationships.

The majority of this information resides in pg_partitioned_table in WarehousePG 7.

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Column Name	WarehousePG 6 Description	WarehousePG 7 Equivalent
parrelid	The object identifier of the table.	pg_partitioned_table.partrelid
parkind	The partition type - R for range or L for list.	pg_partitioned_table.partstrat
parlevel	The partition level of this row: 0 for the top-level parent table, 1 for the first level under the parent table, 2 for the second level, and so on.	Cross-check pg_partitioned_table and `pg_partition_root()/pg_partition_tree()`, similar to how you retrieve pg_partitions.partitionlevel.
paristemplate	Whether or not this row represents a subpartition template definition (`true`) or an actual partitioning level (`false`).	Cross-check pg_partitioned_table.partrelid with gp_partition_template.
parnatts	The number of attributes that define this level.	pg_partitioned_table.partnatts
paratts	An array of the attribute numbers (as in `pg_attribute.attnum`) of the attributes that participate in defining this level.	pg_partitioned_table.partattrs
parclass	The operator class identifier(s) of the partition columns.	pg_partitioned_table.partclass

pg_partition_templates

The WarehousePG 6 `pg_partition_templates` view displays the subpartitions that were created using a subpartition template.

While the information is same as that of the `pg_partitions` view, `pg_partition_templates` displays only those subpartitions created by a subpartition template (cross-check with `pg_partition.paristemplate` of the root partitioned table).

> **Note** WarehousePG 6 assumes that if the root partitioned table has a subpartition template, then all of its subpartitions are created by this subpartition template. In WarehousePG 7 this assumption no longer holds true - you can add any table to a partitioned table with `ATTACH PARTITION`. Ensure that you take this into account when you rewrite your scripts.

Column Name	WarehousePG 6 Description	WarehousePG 7 Equivalent
schemaname	The name of the schema in which the partitioned table resides.	See pg_partitions.schemaname.
tablename	The table name of the top-level parent table.	See pg_partitions.tablename.
partitionname	The name of the subpartition (this is the name to use if referring to the partition in an `ALTER TABLE` command). NULL if the partition was not given a name at create time or generated by an `EVERY` clause.	See pg_partitions.partitionname.
partitiontype	The type of subpartition (range or list).	See pg_partitions.partitiontype.
partitionlevel	The level of this subpartition in the hierarchy.	See pg_partitions.partitionlevel.
partitionrank	For range partitions, the rank of the partition compared to other partitions of the same level.	See pg_partitions.partitionrank.
partitionposition	The rule order position of this subpartition.	See pg_partitions.partitionposition.
partitionlistvalues	For list partitions, the list value(s) associated with this subpartition.	See pg_partitions.partitionlistvalues.
partitionrangestart	For range partitions, the start value of this subpartition.	See pg_partitions.partitionrangestart.
partitionstartinclusive	Whether or not the start value is included in this partition. `true` if the start value is included. `false` if it is excluded.	See pg_partitions.partitionstartinclusive.
partitionrangeend	For range partitions, the end value of this subpartition.	See pg_partitions.partitionrangend.
partitionendinclusive	Whether or not the end value is included in this partition. `true` if the end value is included. `false` if it is excluded.	See pg_partitions.partitionendinclusive.
partitioneveryclause	The `EVERY` clause (interval) of this subpartition.	See pg_partitions.partitioneveryclause.
partitionisdefault	Whether or not this is a default subpartition. `true` if this is the default, otherwise `false`.	See pg_partitions.partitionisdefault.
partitionboundary	The entire partition specification for this subpartition.	See pg_partitions.partitionboundary.

pg_partition_encoding

The WarehousePG 6 `pg_partition_encoding` table describes the available column compression options for a subpartition template. This information is stored in gp_partition_template in WarehousePG 7.

You must perform some text filtering to retrieve the per-column encoding information in WarehousePG 7 in the same format as that of `pg_partition_encoding`.

Column Name	WarehousePG 6 Description	WarehousePG 7 Equivalent
parencoid	The object identifier of the parent partition of this subpartition template.	`gp_partition_template`
parencattnum	The attribute number of the column for which the encoding option applies.	`pg_get_expr(template, <root_partition_oid>)`
parencattoptions	The storage option of this column.	`pg_get_expr(template, <root_partition_oid>)`

Composing a Similar View in WarehousePG 7

You can retrieve a one-line definition of the template using `pg_get_expr()` as follows:

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```
SELECT level, pg_get_expr(template, relid) from gp_partition_template where relid::regclass::text = '<tablename>';
 level |                                                
```

3.15 Enabling iptables (Optional)

On Linux systems, you can configure and enable the `iptables` firewall to work with WarehousePG.

> **Note** WarehousePG performance might be impacted when `iptables` is enabled. You should test the performance of your application with `iptables` enabled to ensure that performance is acceptable.

For more information about `iptables` see the `iptables` and firewall documentation for your operating system. See also Deactivating SELinux and Firewall Software.

How to Enable iptables

1. As `gpadmin`, run this command on the WarehousePG coordinator host to stop WarehousePG:

   ```
   $ gpstop -a
   ```

2. On the WarehousePG hosts:

   1. Update the file `/etc/sysconfig/iptables` based on the Example iptables Rules.

   2. As root user, run these commands to enable `iptables`:

      ```
      # chkconfig iptables on
      # service iptables start
      ```

3. As gpadmin, run this command on the WarehousePG coordinator host to start WarehousePG:

   ```
   $ gpstart -a
   ```

> **Caution** After enabling `iptables`, this error in the `/var/log/messages` file indicates that the setting for the `iptables` table is too low and needs to be increased.

```
ip_conntrack: table full, dropping packet.
```

As root, run this command to view the `iptables` table value:

```
# sysctl net.ipv4.netfilter.ip_conntrack_max
```

To ensure that the WarehousePG workload does not overflow the `iptables` table, as root, set it to the following value:

```
# sysctl net.ipv4.netfilter.ip_conntrack_max=6553600
```

The value might need to be adjusted for your hosts. To maintain the value after reboot, you can update the `/etc/sysctl.conf` file as discussed in Setting the WarehousePG Recommended OS Parameters.

Parent topic: Installing and Upgrading WarehousePG

Example iptables Rules

When `iptables` is enabled, `iptables` manages the IP communication on the host system based on configuration settings (rules). The example rules are used to configure `iptables` for WarehousePG coordinator host, standby coordinator host, and segment hosts.

- Example Coordinator and Standby Coordinator iptables Rules
- Example Segment Host iptables Rules

The two sets of rules account for the different types of communication WarehousePG expects on the coordinator (primary and standby) and segment hosts. The rules should be added to the `/etc/sysconfig/iptables` file of the WarehousePG hosts. For WarehousePG, `iptables` rules should allow the following communication:

- For customer facing communication with the WarehousePG coordinator, allow at least `postgres` and `28080` (`eth1` interface in the example).
- For WarehousePG cluster interconnect, allow communication using `tcp`, `udp`, and `icmp` protocols (`eth4` and `eth5` interfaces in the example).

  The network interfaces that you specify in the `iptables` settings are the interfaces for the WarehousePG hosts that you list in the hostfile_gpinitsystem file. You specify the file when you run the `gpinitsystem` command to initialize a WarehousePG cluster. See Initializing WarehousePG for information about the hostfile_gpinitsystem file and the `gpinitsystem` command.

- For the administration network on a WarehousePG DCA, allow communication using `ssh`, `ntp`, and `icmp` protocols. (`eth0` interface in the example).

In the `iptables` file, each append rule command (lines starting with `-A`) is a single line.

The example rules should be adjusted for your configuration. For example:

- The append command, the `-A` lines and connection parameter `-i` should match the connectors for your hosts.
- the CIDR network mask information for the source parameter `-s` should match the IP addresses for your network.

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Example Coordinator and Standby Coordinator iptables Rules

Example `iptables` rules with comments for the `/etc/sysconfig/iptables` file on the WarehousePG coordinator host and standby coordinator host.

```
*filter
# Following 3 are default rules. If the packet passes through
# the rule set it gets these rule.
# Drop all inbound packets by default.
# Drop all forwarded (routed) packets.
# Let anything outbound go through.
:INPUT DROP [0:0]
:FORWARD DROP [0:0]
:OUTPUT ACCEPT [0:0]
# Accept anything on the loopback interface.
-A INPUT -i lo -j ACCEPT
# If a connection has already been established allow the
# remote host packets for the connection to pass through.
-A INPUT -m state --state ESTABLISHED,RELATED -j ACCEPT
# These rules let all tcp and udp through on the standard
# interconnect IP addresses and on the interconnect interfaces.
# NOTE: gpsyncmaster uses random tcp ports in the range 1025 to 65535
# and WarehousePG uses random udp ports in the range 1025 to 65535.
-A INPUT -i eth4 -p udp -s 192.0.2.0/22 -j ACCEPT
-A INPUT -i eth5 -p udp -s 198.51.100.0/22 -j ACCEPT
-A INPUT -i eth4 -p tcp -s 192.0.2.0/22 -j ACCEPT --syn -m state --state NEW
-A INPUT -i eth5 -p tcp -s 198.51.100.0/22 -j ACCEPT --syn -m state --state NEW
\# Allow udp/tcp ntp connections on the admin network on WarehousePG DCA.
-A INPUT -i eth0 -p udp --dport ntp -s 203.0.113.0/21 -j ACCEPT
-A INPUT -i eth0 -p tcp --dport ntp -s 203.0.113.0/21 -j ACCEPT --syn -m state --state NEW
# Allow ssh on all networks (This rule can be more strict).
-A INPUT -p tcp --dport ssh -j ACCEPT --syn -m state --state NEW
# Allow WarehousePG on all networks.
-A INPUT -p tcp --dport postgres -j ACCEPT --syn -m state --state NEW
# Allow ping and any other icmp traffic on the interconnect networks.
-A INPUT -i eth4 -p icmp -s 192.0.2.0/22 -j ACCEPT
-A INPUT -i eth5 -p icmp -s 198.51.100.0/22 -j ACCEPT
\# Allow ping only on the admin network on WarehousePG DCA.
-A INPUT -i eth0 -p icmp --icmp-type echo-request -s 203.0.113.0/21 -j ACCEPT
# Log an error if a packet passes through the rules to the default
# INPUT rule (a DROP).
-A INPUT -m limit --limit 5/min -j LOG --log-prefix "iptables denied: " --log-level 7
COMMIT
```

Example Segment Host iptables Rules

Example `iptables` rules for the `/etc/sysconfig/iptables` file on the WarehousePG segment hosts. The rules for segment hosts are similar to the coordinator rules with fewer interfaces and fewer `udp` and `tcp` services.

```
*filter
:INPUT DROP
:FORWARD DROP
:OUTPUT ACCEPT
-A INPUT -i lo -j ACCEPT
-A INPUT -m state --state ESTABLISHED,RELATED -j ACCEPT
-A INPUT -i eth2 -p udp -s 192.0.2.0/22 -j ACCEPT
-A INPUT -i eth3 -p udp -s 198.51.100.0/22 -j ACCEPT
-A INPUT -i eth2 -p tcp -s 192.0.2.0/22 -j ACCEPT --syn -m state --state NEW
-A INPUT -i eth3 -p tcp -s 198.51.100.0/22 -j ACCEPT --syn -m state --state NEW
-A INPUT -p tcp --dport ssh -j ACCEPT --syn -m state --state NEW
-A INPUT -i eth2 -p icmp -s 192.0.2.0/22 -j ACCEPT
-A INPUT -i eth3 -p icmp -s 198.51.100.0/22 -j ACCEPT
-A INPUT -i eth0 -p icmp --icmp-type echo-request -s 203.0.113.0/21 -j ACCEPT
-A INPUT -m limit --limit 5/min -j LOG --log-prefix "iptables denied: " --log-level 7
COMMIT
```

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3.16 Installation Utilities Reference

References for the command-line management utilities used to install and initialize a WarehousePG cluster.

For a full reference of all WarehousePG utilities, see the WarehousePG Utility Guide.

The following WarehousePG management utilities are located in `$GPHOME/bin`.

- gpactivatestandby
- gpaddmirrors
- gpcheckperf
- gpdeletesystem
- gpinitstandby
- gpinitsystem
- gpssh
- gpssh-exkeys
- gpstart
- gpstop
- gpsync

Parent topic: Installing and Upgrading WarehousePG

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3.17 WarehousePG Environment Variables

Reference of the environment variables to set for WarehousePG.

Set these in your user's startup shell profile (such as `~/.bashrc` or `~/.bash_profile`), or in `/etc/profile` if you want to set them for all users.

- Required Environment Variables
- Optional Environment Variables

Parent topic: Installing and Upgrading WarehousePG

Required Environment Variables

> **Note** `GPHOME`, `PATH` and `LD_LIBRARY_PATH` can be set by sourcing the `greenplum_path.sh` file from your WarehousePG installation directory

Parent topic: WarehousePG Environment Variables

GPHOME

This is the installed location of your WarehousePG software. For example:

```
GPHOME=/usr/edb/whpg7
export GPHOME
```

PATH

Your `PATH` environment variable should point to the location of the WarehousePG `bin` directory. For example:

```
PATH=$GPHOME/bin:$PATH
export PATH
```

LD_LIBRARY_PATH

The `LD_LIBRARY_PATH` environment variable should point to the location of the WarehousePG/PostgreSQL library files. For example:

```
LD_LIBRARY_PATH=$GPHOME/lib
export LD_LIBRARY_PATH
```

COORDINATOR_DATA_DIRECTORY

This should point to the directory created by the gpinitsystem utility in the coordinator data directory location. For example:

```
COORDINATOR_DATA_DIRECTORY=/data/coordinator/gpseg-1
export COORDINATOR_DATA_DIRECTORY
```

Optional Environment Variables

The following are standard PostgreSQL environment variables, which are also recognized in WarehousePG. You may want to add the connection-related environment variables to your profile for convenience, so you do not have to type so many options on the command line for client connections. Note that these environment variables should be set on the WarehousePG coordinator host only.

Parent topic: WarehousePG Environment Variables

PGAPPNAME

The name of the application that is usually set by an application when it connects to the server. This name is displayed in the activity view and in log entries. The `PGAPPNAME` environmental variable behaves the same as the `application_name` connection parameter. The default value for `application_name` is `psql`. The name cannot be longer than 63 characters.

PGDATABASE

The name of the default database to use when connecting.

PGHOST

The WarehousePG coordinator host name.

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PGHOSTADDR

The numeric IP address of the coordinator host. This can be set instead of or in addition to `PGHOST` to avoid DNS lookup overhead.

PGPASSWORD

The password used if the server demands password authentication. Use of this environment variable is not recommended for security reasons (some operating systems allow non-root users to see process environment variables via `ps`). Instead consider using the `~/.pgpass` file.

PGPASSFILE

The name of the password file to use for lookups. If not set, it defaults to `~/.pgpass`. See the topic about The Password File in the PostgreSQL documentation for more information.

PGOPTIONS

Sets additional configuration parameters for the WarehousePG coordinator server.

PGPORT

The port number of the WarehousePG server on the coordinator host. The default port is 5432.

PGUSER

The WarehousePG user name used to connect.

PGDATESTYLE

Sets the default style of date/time representation for a session. (Equivalent to `SET datestyle TO...`)

PGTZ

Sets the default time zone for a session. (Equivalent to `SET timezone TO...`)

PGCLIENTENCODING

Sets the default client character set encoding for a session. (Equivalent to `SET client_encoding TO...`)

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3.18 Example Ansible Playbook

A sample Ansible playbook to install a WarehousePG software release onto the hosts that will comprise a WarehousePG cluster.

This Ansible playbook shows how tasks described in [Installing WarehousePG]() might be automated using Ansible.

> **Important** This playbook is provided as an *example only* to illustrate how WarehousePG cluster configuration and software installation tasks can be automated using provisioning tools such as Ansible, Chef, or Puppet. Presented as an example.

The example playbook is designed for use with RedHat. It creates the `gpadmin` user, installs the WarehousePG software release, sets the owner and group of the installed software to `gpadmin`, and sets the Pam security limits for the `gpadmin` user.

You can revise the script to work with your operating system platform and to perform additional host configuration tasks.

Following are steps to use this Ansible playbook.

1. Install Ansible on the control node using your package manager. See the Ansible documentation for help with installation.
2. Set up passwordless SSH from the control node to all hosts that will be a part of the WarehousePG cluster. You can use the `ssh-copy-id` command to install your public SSH key on each host in the cluster. Alternatively, your provisioning software may provide more convenient ways to securely install public keys on multiple hosts.
3. Create an Ansible inventory by creating a file called `hosts` with a list of the hosts that will comprise your WarehousePG cluster. For example:

   ```
   cdw
   sdw1
   sdw2
   ...
   ```

   This file can be edited and used with the WarehousePG `gpssh-exkeys` and `gpinitsystem` utilities later on.
4. Copy the playbook code below to a file `ansible-playbook.yml` on your Ansible control node.
5. Edit the playbook variables at the top of the playbook, such as the `gpadmin` administrative user and password to create, and the version of WarehousePG you are installing.
6. Run the playbook, passing the package to be installed to the `package_path` parameter.

   ```
   ansible-playbook ansible-playbook.yml -i hosts -e package_path=./greenplum-db-7.0.0-rhel8-x86_64.rpm
   ```

Ansible Playbook - WarehousePG Installation for RedHat

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```
---

- hosts: all
  vars:
    - version: "7.0.0"
    - greenplum_admin_user: "gpadmin"
    - greenplum_admin_password: "changeme"
    # - package_path: passed via the command line with: -e package_path=./greenplum-db-7.0.0-rhel8-x86_64.rpm
  remote_user: root
  become: yes
  become_method: sudo
  connection: ssh
  gather_facts: yes
  tasks:
    - name: create greenplum admin user
      user:
        name: "{{ greenplum_admin_user }}"
        password: "{{ greenplum_admin_password | password_hash('sha512', 'DvkPtCtNH+UdbePZfm9muQ9pU') }}"
    - name: copy package to host
      copy:
        src: "{{ package_path }}"
        dest: /tmp
    - name: install package
      yum:
        name: "/tmp/{{ package_path | basename }}"
        state: present
    - name: cleanup package file from host
      file:
        path: "/tmp/{{ package_path | basename }}"
        state: absent
    - name: find install directory
      find:
        paths: /usr/local
        patterns: 'greenplum*'
        file_type: directory
      register: installed_dir
    - name: change install directory ownership
      file:
        path: '{{ item.path }}'
        owner: "{{ greenplum_admin_user }}"
        group: "{{ greenplum_admin_user }}"
        recurse: yes
      with_items: "{{ installed_dir.files }}"
    - name: update pam_limits
      pam_limits:
        domain: "{{ greenplum_admin_user }}"
        limit_type: '-'
        limit_item: "{{ item.key }}"
        value: "{{ item.value }}"
      with_dict:
        nofile: 524288
        nproc: 131072
    - name: find installed greenplum version
      shell: . /usr/edb/whpg7/greenplum_path.sh && /usr/edb/whpg7/bin/postgres --gp-version
      register: postgres_gp_version
    - name: fail if the correct greenplum version is not installed
      fail:
        msg: "Expected greenplum version {{ version }}, but found '{{ postgres_gp_version.stdout }}'"
      when: "version is not defined or version not in postgres_gp_version.stdout"
```

When the playbook has run successfully, you can proceed with Creating the Data Storage Areas and Initializing WarehousePG.

Parent topic: Installing and Upgrading WarehousePG

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4 WarehousePG administrator guide

Information about configuring, managing and monitoring WarehousePG installations, and administering, monitoring, and working with databases. The guide also contains information about WarehousePG architecture and concepts such as parallel processing.

- WarehousePG Concepts
  This section provides an overview of WarehousePG components and features such as high availability, parallel data loading features, and management utilities.
- Managing a WarehousePG cluster
  This section describes basic system administration tasks performed by a WarehousePG cluster administrator.
- Managing WarehousePG Access
  Securing WarehousePG includes protecting access to the database through network configuration, database user authentication, and encryption.
- Data Distribution and Skew
  WarehousePG relies on even distribution of data across segments.
- DDL: Defining Database Objects
  This section covers data definition language (DDL) in WarehousePG and how to create and manage database objects.
- DML: Inserting, Updating and Deleting
  This section provides information about manipulating data and concurrent access in WarehousePG.
- Querying Data
  This topic provides information about using SQL in WarehousePGs.
- Analytics guide Advanced data analytics
- External Data Sources
  Both external and foreign tables provide access to data stored in data sources outside of WarehousePG as if the data were stored in regular database tables. You can read data from and write data to external and foreign tables.
- Loading and Unloading Data
  The topics in this section describe methods for loading and writing data into and out of a WarehousePG, and how to format data files.
- Managing Performance
  The topics in this section cover WarehousePG performance management, including how to monitor performance and how to configure workloads to prioritize resource utilization.
- Retrieving Query Results with a Parallel Retrieve Cursor A *parallel retrieve cursor*is an enhanced cursor implementation that you can use to create a special kind of cursor on the WarehousePG coordinator node, and retrieve query results, on demand and in parallel, directly from the WarehousePG segments.

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4.1 WarehousePG Concepts

This section provides an overview of WarehousePG components and features such as high availability, parallel data loading features, and management utilities.

- About the WarehousePG Architecture
  WarehousePG is a massively parallel processing (MPP) database server with an architecture specially designed to manage large-scale analytic data warehouses and business intelligence workloads.
- About Management and Monitoring Utilities
  WarehousePG provides standard command-line utilities for performing common monitoring and administration tasks.
- About Concurrency Control in WarehousePG
  WarehousePG uses the PostgreSQL Multiversion Concurrency Control (MVCC) model to manage concurrent transactions for heap tables.
- About Parallel Data Loading
  This topic provides a short introduction to WarehousePG data loading features.
- About Redundancy and Failover in WarehousePG
  This topic provides a high-level overview of WarehousePG high availability features.
- About Database Statistics in WarehousePG
  An overview of statistics gathered by the ANALYZE command in WarehousePG.

Parent topic: WarehousePG Administrator Guide

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4.1.1 About the WarehousePG Architecture

WarehousePG is a massively parallel processing (MPP) database server with an architecture specially designed to manage large-scale analytic data warehouses and business intelligence workloads.

MPP (also known as a *shared nothing* architecture) refers to systems with two or more processors that cooperate to carry out an operation, each processor with its own memory, operating system and disks. WarehousePG uses this high-performance system architecture to distribute the load of multi-terabyte data warehouses, and can use all of a system's resources in parallel to process a query.

WarehousePG is based on PostgreSQL open-source technology. It is essentially several PostgreSQL disk-oriented database instances acting together as one cohesive database management system (DBMS). It is based on PostgreSQL 12, and in most cases is very similar to PostgreSQL with regard to SQL support, features, configuration options, and end-user functionality. Database users interact with WarehousePG as they would with a regular PostgreSQL DBMS.

WarehousePG can use the append-optimized (AO) storage format for bulk loading and reading of data, and provides performance advantages over HEAP tables. Append-optimized storage provides checksums for data protection, compression and row/column orientation. Both row-oriented or column-oriented append-optimized tables can be compressed.

The main differences between WarehousePG and PostgreSQL are as follows:

- GPORCA is leveraged for query planning, in addition to the Postgres-based planner.
- WarehousePG can use append-optimized storage.
- WarehousePG has the option to use column storage, data that is logically organized as a table, using rows and columns that are physically stored in a column-oriented format, rather than as rows. Column storage can only be used with append-optimized tables. Column storage is compressible. It also can provide performance improvements as you only need to return the columns of interest to you. All compression algorithms can be used with either row or column-oriented tables, but Run-Length Encoded (RLE) compression can only be used with column-oriented tables. WarehousePG provides compression on all Append-Optimized tables that use column storage.

The internals of PostgreSQL have been modified or supplemented to support the parallel structure of WarehousePG. For example, the system catalog, optimizer, query executor, and transaction manager components have been modified and enhanced to be able to run queries simultaneously across all of the parallel PostgreSQL database instances. The WarehousePG *interconnect* (the networking layer) enables communication between the distinct PostgreSQL instances and allows the system to behave as one logical database.

WarehousePG also can use declarative partitions and sub-partitions to implicitly generate partition constraints.

WarehousePG also includes features designed to optimize PostgreSQL for business intelligence (BI) workloads. For example, WarehousePG has added parallel data loading (external tables), resource management, query optimizations, and storage enhancements, which are not found in standard PostgreSQL. Many features and optimizations developed by WarehousePG make their way into the PostgreSQL community. For example, table partitioning is a feature first developed by WarehousePG, and it is now in standard PostgreSQL.

WarehousePG queries use a Volcano-style query engine model, where the execution engine takes an execution plan and uses it to generate a tree of physical operators, evaluates tables through physical operators, and delivers results in a query response.

WarehousePG stores and processes large amounts of data by distributing the data and processing workload across several servers or *hosts*. WarehousePG is an *array* of individual databases based upon PostgreSQL 12 working together to present a single database image. The *coordinator* is the entry point to the WarehousePG cluster. It is the database instance to which clients connect and submit SQL statements. The coordinator coordinates its work with the other database instances in the system, called *segments*, which store and process the data.

WarehousePG Architecture

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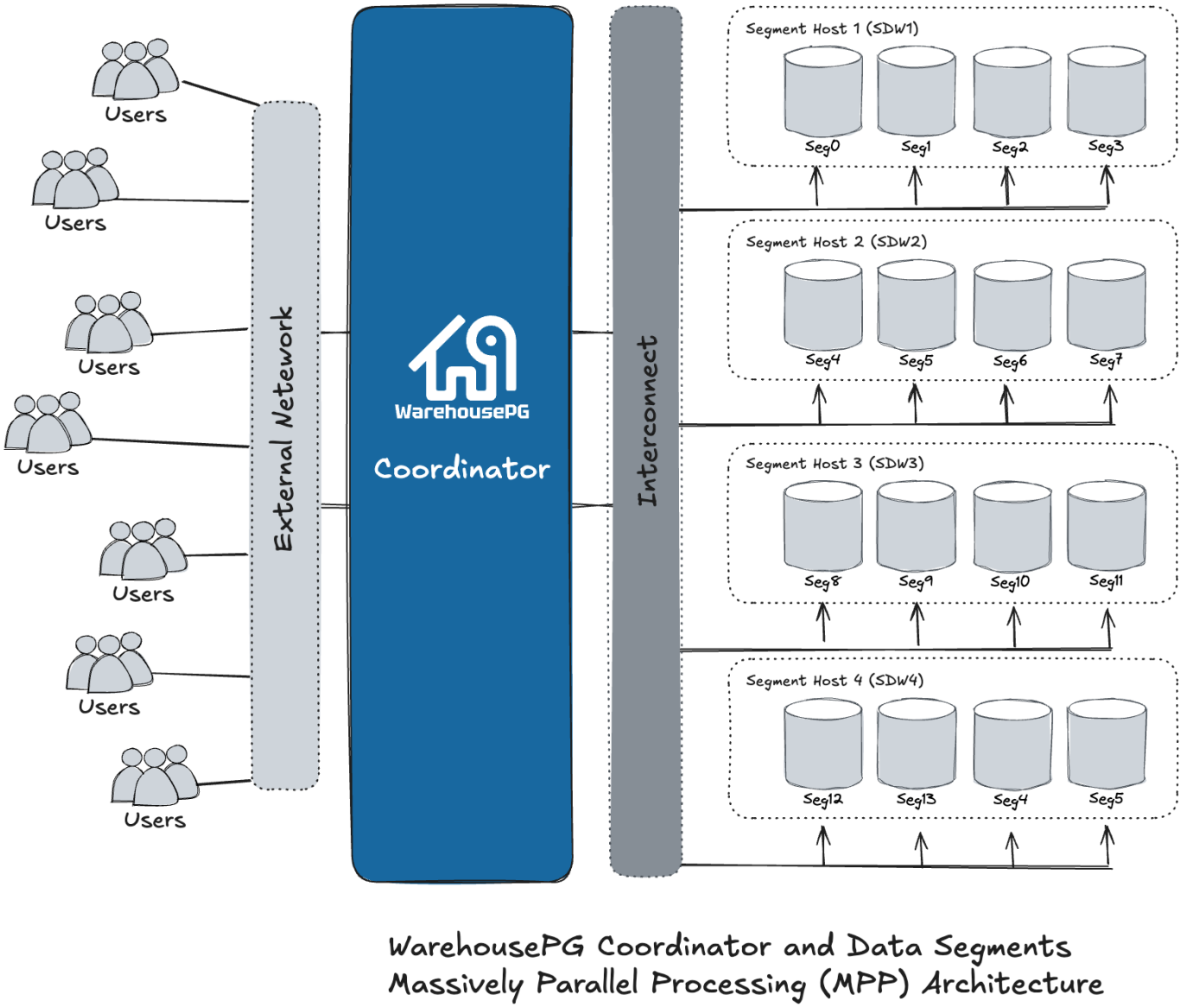

WarehousePG Coordinator and Data Segments
Massively Parallel Processing (MPP) Architecture

The following topics describe the components that make up a WarehousePG cluster and how they work together.

- About the WarehousePG Coordinator
- About the WarehousePG Segments
- About the WarehousePG Interconnect
- About ETL Hosts for Data Loading

About the WarehousePG Coordinator

The WarehousePG coordinator is the entry to the WarehousePG cluster, accepting client connections and SQL queries, and distributing work to the segment instances.

WarehousePG end-users interact with WarehousePG (through the coordinator) as they would with a typical PostgreSQL database. They connect to the database using client programs such as `psql` or application programming interfaces (APIs) such as JDBC, ODBC or libpq (the PostgreSQL C API).

The coordinator is where the *global system catalog* resides. The global system catalog is the set of system tables that contain metadata about the WarehousePG cluster itself. The coordinator does not contain any user data; data resides only on the *segments*. The coordinator authenticates client connections, processes incoming SQL commands, distributes workloads among segments, coordinates the results returned by each segment, and presents the final results to the client program.

WarehousePG uses Write-Ahead Logging (WAL) for coordinator/standby coordinator mirroring. In WAL-based logging, all modifications are written to the log before being applied, to ensure data integrity for any in-process operations.

Coordinator Redundancy

You may optionally deploy a *backup* or *mirror* of the coordinator instance. A backup coordinator host serves as a *warm standby* if the primary coordinator host becomes nonoperational. You can deploy the standby coordinator on a designated redundant coordinator host or on one of the segment hosts.

The standby coordinator is kept up to date by a transaction log replication process, which runs on the standby coordinator host and synchronizes the data between the primary and standby coordinator hosts. If the primary coordinator fails, the log replication process shuts down, and an administrator can activate the standby coordinator in its place. When the standby coordinator is active, the replicated logs are used to reconstruct the state of the coordinator host at the time of the last successfully committed transaction.

Since the coordinator does not contain any user data, only the system catalog tables need to be synchronized between the primary and backup copies. When these tables are updated, changes automatically copy over to the standby coordinator so it is always synchronized with the primary.

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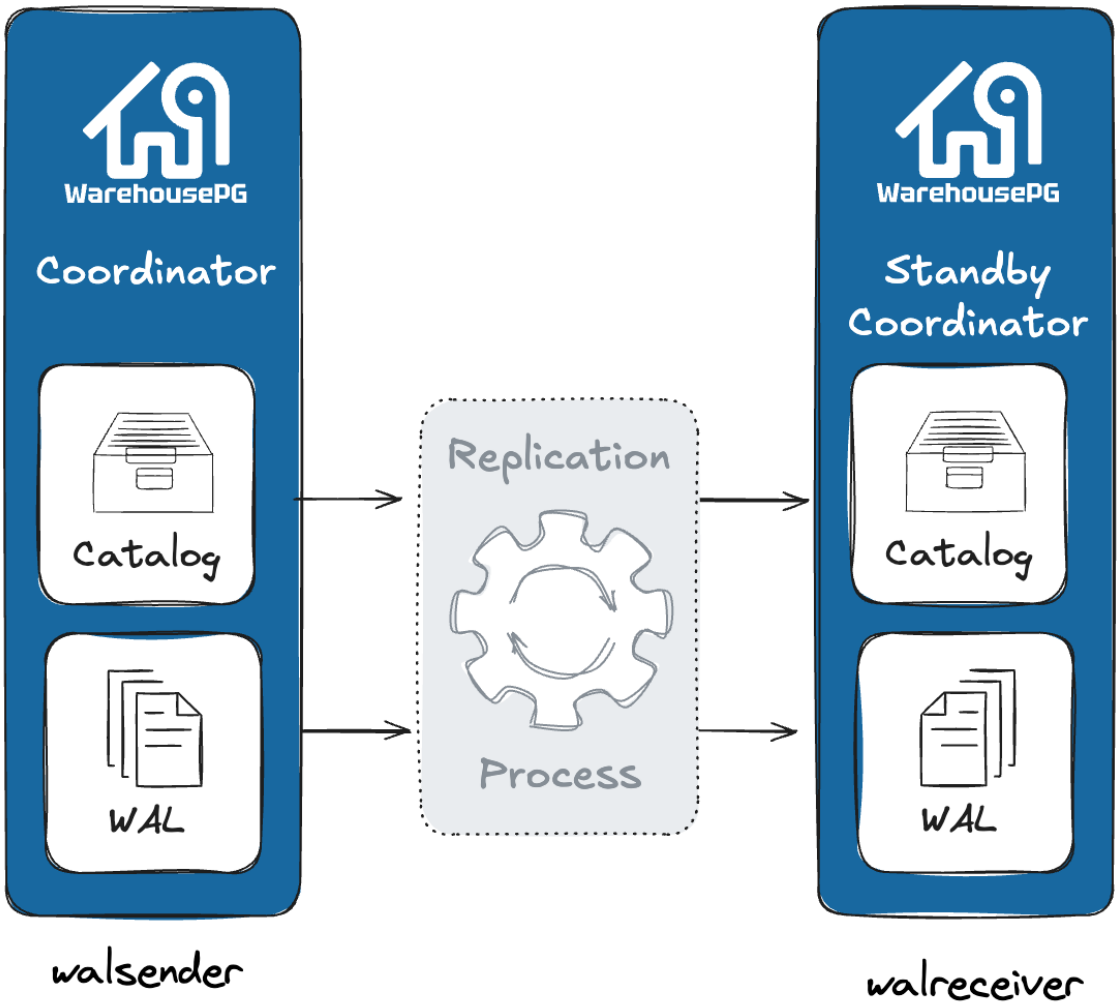

About the WarehousePG Segments

WarehousePG segment instances are independent PostgreSQL databases that each store a portion of the data and perform the majority of query processing.

When a user connects to the database via the WarehousePG coordinator and issues a query, processes are created in each segment database to handle the work of that query. For more information about query processes, seeAbout WarehousePG Query Processing.

User-defined tables and their indexes are distributed across the available segments in a WarehousePG cluster; each segment contains a distinct portion of data. The database server processes that serve segment data run under the corresponding segment instances. Users interact with segments in a WarehousePG cluster through the coordinator.

A server that runs a segment instance is called a *segment host*. A segment host typically runs from two to eight WarehousePG segments, depending on the CPU cores, RAM, storage, network interfaces, and workloads. Segment hosts are expected to be identically configured. The key to obtaining the best performance from WarehousePG is to distribute data and workloads *evenly* across a large number of equally capable segments so that all segments begin working on a task simultaneously and complete their work at the same time.

Segment Redundancy

When you deploy your WarehousePG cluster, you have the option to configure *mirror* segments. Mirror segments allow database queries to fail over to a backup segment if the primary segment becomes unavailable. Mirroring is a requirement for WarehousePG-supported production WarehousePG clusters.

A mirror segment must always reside on a different host than its primary segment. Mirror segments can be arranged across the hosts in the system in one of two standard configurations, or in a custom configuration you design. The default configuration, called *group* mirroring, places the mirror segments for all primary segments on one other host. Another option, called *spread* mirroring, spreads mirrors for each host's primary segments over the remaining hosts. Spread mirroring requires that there be more hosts in the system than there are primary segments on the host. On hosts with multiple network interfaces, the primary and mirror segments are distributed equally among the interfaces. The following figure shows how table data is distributed across the segments when the default group mirroring option is configured.

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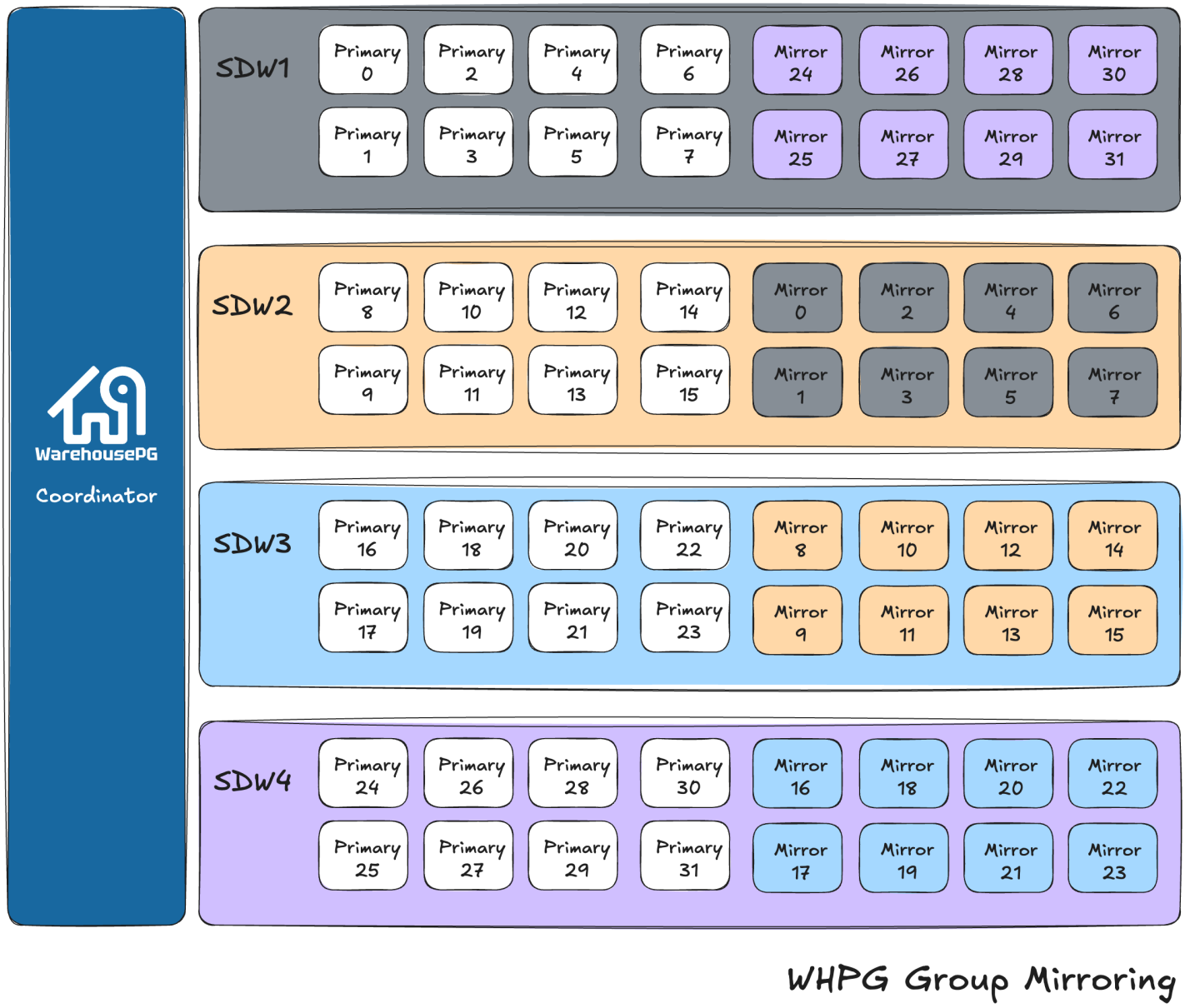

WHPG Group Mirroring

Segment Failover and Recovery

When mirroring is enabled in a WarehousePG cluster, the system automatically fails over to the mirror copy if a primary copy becomes unavailable. A WarehousePG cluster can remain operational if a segment instance or host goes down only if all portions of data are available on the remaining active segments.

If the coordinator cannot connect to a segment instance, it marks that segment instance as *invalid* in the WarehousePG cluster catalog. The segment instance remains invalid and out of operation until an administrator brings that segment back online. An administrator can recover a failed segment while the system is up and running. The recovery process copies over only the changes that were missed while the segment was nonoperational.

If you do not have mirroring enabled and a segment becomes invalid, the system automatically shuts down. An administrator must recover all failed segments before operations can continue.

Example Segment Host Hardware Stack

Regardless of the hardware platform you choose, a production WarehousePG processing node (a segment host) is typically configured as described in this section.

The segment hosts do the majority of database processing, so the segment host servers are configured in order to achieve the best performance possible from your WarehousePG cluster. WarehousePG's performance will be as fast as the slowest segment server in the array. Therefore, it is important to ensure that the underlying hardware and operating systems that are running WarehousePG are all running at their optimal performance level. It is also advised that all segment hosts in a WarehousePG cluster have identical hardware resources and configurations.

Segment hosts should also be dedicated to WarehousePG operations only. To get the best query performance, you do not want WarehousePG competing with other applications for machine or network resources.

The following diagram shows an example WarehousePG segment host hardware stack. The number of effective CPUs on a host is the basis for determining how many primary WarehousePG segment instances to deploy per segment host. This example shows a host with two effective CPUs (one dual-core CPU). Note that there is one primary segment instance (or primary/mirror pair if using mirroring) per CPU core.

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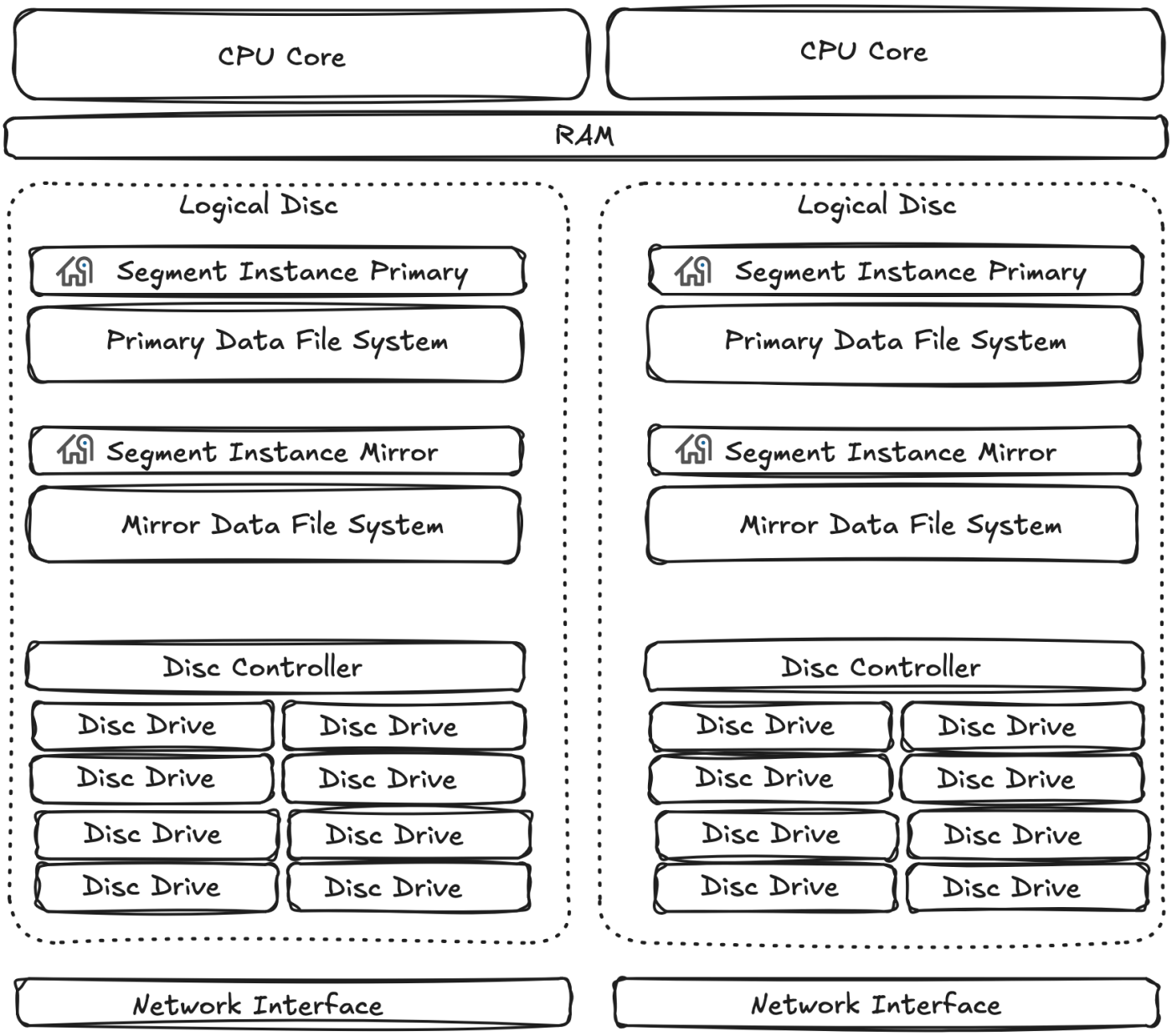

Example Segment Disk Layout

Each CPU is typically mapped to a logical disk. A logical disk consists of one primary file system (and optionally a mirror file system) accessing a pool of physical disks through an I/O channel or disk controller. The logical disk and file system are provided by the operating system. Most operating systems provide the ability for a logical disk drive to use groups of physical disks arranged in RAID arrays.

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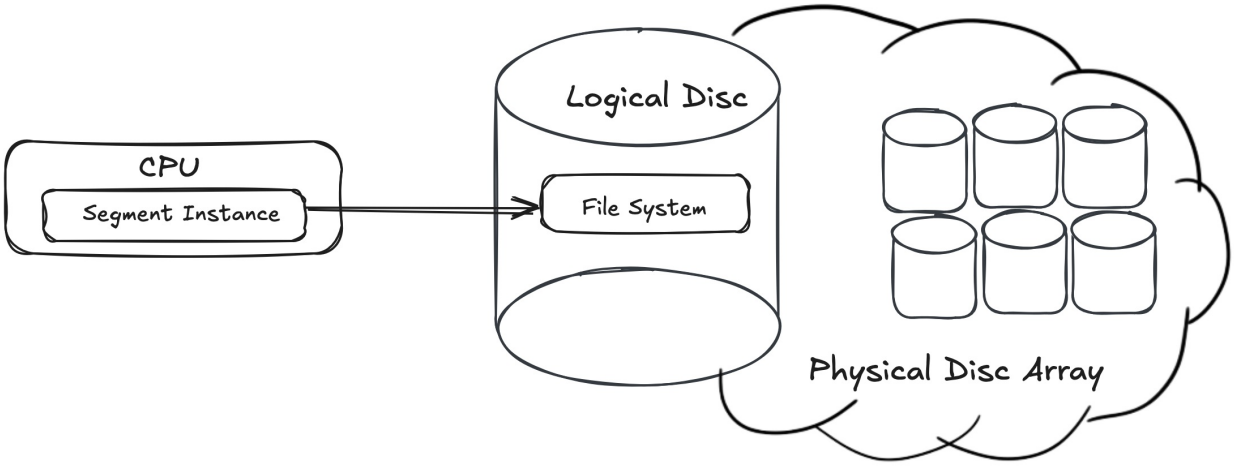

Depending on the hardware platform you choose, different RAID configurations offer different performance and capacity levels. WarehousePG supports and certifies a number of reference hardware platforms and operating systems. Check with your sales account representative for the recommended configuration on your chosen platform.

About the WarehousePG Interconnect

The interconnect is the networking layer of the WarehousePG architecture.

The *interconnect* refers to the inter-process communication between segments and the network infrastructure on which this communication relies. The WarehousePG interconnect uses a standard Ethernet switching fabric. For performance reasons, a 10-Gigabit system, or faster, is recommended.

By default, the interconnect uses User Datagram Protocol with flow control (UDPIFC) for interconnect traffic to send messages over the network. The WarehousePG software performs packet verification beyond what is provided by UDP. This means the reliability is equivalent to Transmission Control Protocol (TCP), and the performance and scalability exceeds TCP. If the interconnect is changed to TCP, WarehousePG has a scalability limit of 1000 segment instances. With UDPIFC as the default protocol for the interconnect, this limit is not applicable.

Interconnect Redundancy

A highly available interconnect can be achieved by deploying dual 10 Gigabit Ethernet switches on your network, and redundant 10 Gigabit connections to the WarehousePG coordinator and segment host servers.

Network Interface Configuration

A segment host typically has multiple network interfaces designated to WarehousePG interconnect traffic. The coordinator host typically has additional external network interfaces in addition to the interfaces used for interconnect traffic.

Depending on the number of interfaces available, you will want to distribute interconnect network traffic across the number of available interfaces. This is done by assigning segment instances to a particular network interface and ensuring that the primary segments are evenly balanced over the number of available interfaces.

This is done by creating separate host address names for each network interface. For example, if a host has four network interfaces, then it would have four corresponding host addresses, each of which maps to one or more primary segment instances. The `/etc/hosts` file should be configured to contain not only the host name of each machine, but also all interface host addresses for all of the WarehousePG hosts (coordinator, standby coordinator, segments, and ETL hosts).

With this configuration, the operating system automatically selects the best path to the destination. WarehousePG automatically balances the network destinations to maximize parallelism.

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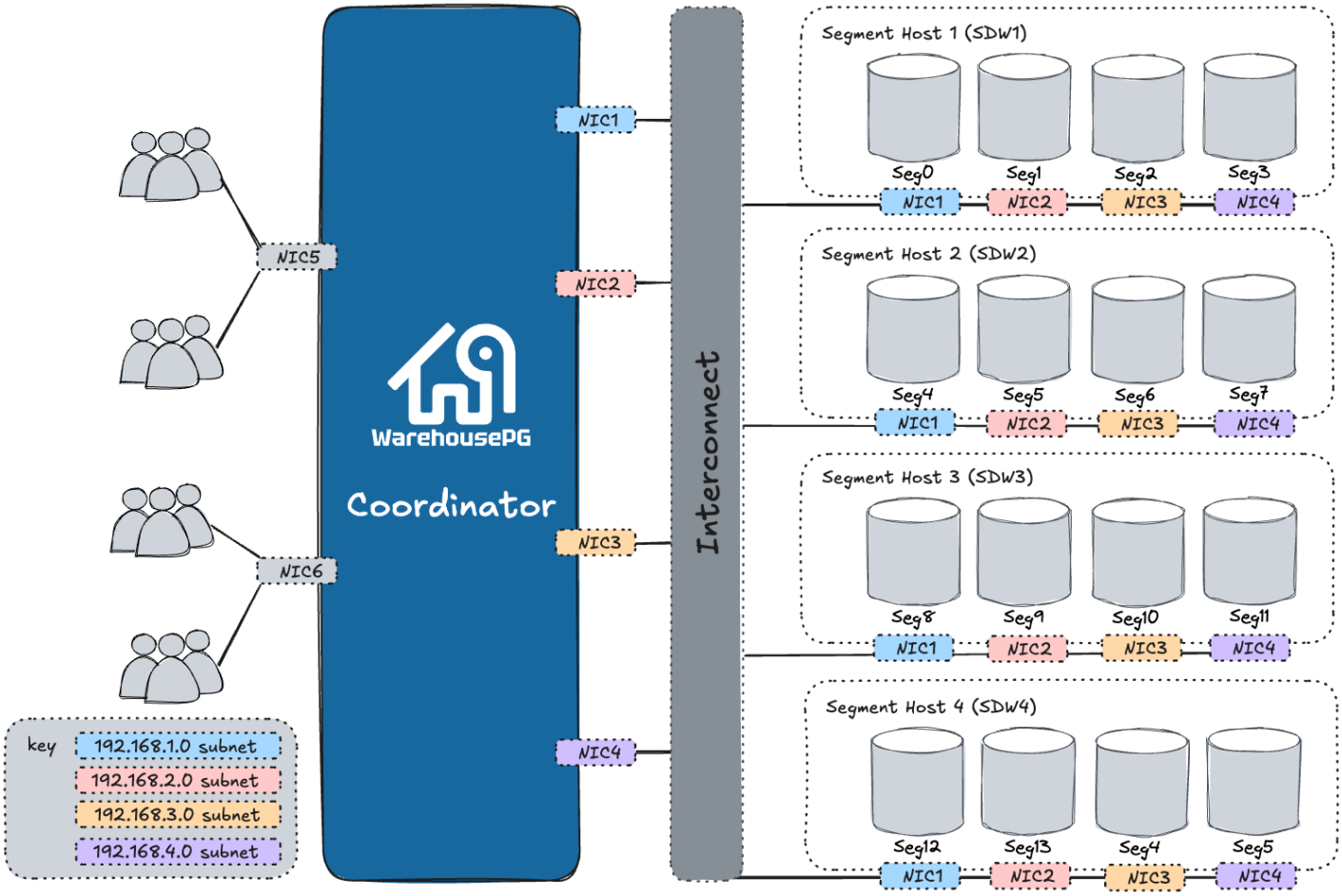

Switch Configuration

When using multiple 10 Gigabit Ethernet switches within your WarehousePG cluster, evenly divide the number of subnets between each switch. In this example configuration, if we had two switches, NICs 1 and 2 on each host would use switch 1 and NICs 3 and 4 on each host would use switch 2. For the coordinator host, the host name bound to NIC 1 (and therefore using switch 1) is the effective coordinator host name for the array. Therefore, if deploying a warm standby coordinator for redundancy purposes, the standby coordinator should map to a NIC that uses a different switch than the primary coordinator.

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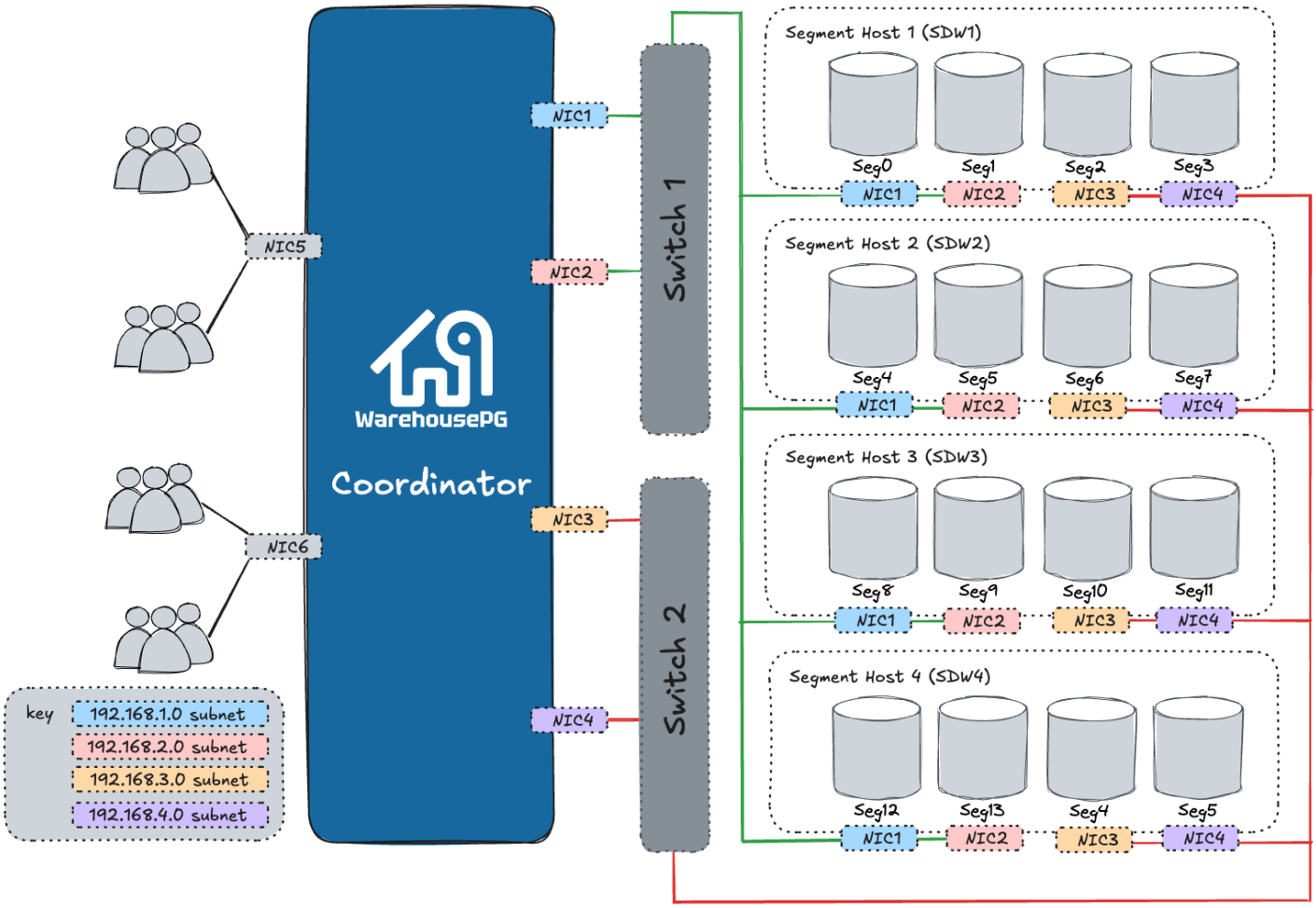

About ETL Hosts for Data Loading

WarehousePG supports fast, parallel data loading with its external tables feature. By using external tables in conjunction with WarehousePG's parallel file server (`gpfdist`), administrators can achieve maximum parallelism and load bandwidth from their WarehousePG cluster. Many production systems deploy designated ETL servers for data loading purposes. These machines run the WarehousePG parallel file server (`gpfdist`), but not WarehousePG instances.

One advantage of using the `gpfdist` file server program is that it ensures that all of the segments in your WarehousePG cluster are fully utilized when reading from external table data files.

The `gpfdist` program can serve data to the segment instances at an average rate of about 350 MB/s for delimited text formatted files and 200 MB/s for CSV formatted files. Therefore, you should consider the following options when running `gpfdist` in order to maximize the network bandwidth of your ETL systems:

- If your ETL machine is configured with multiple network interface cards (NICs) as described in Network Interface Configuration, run one instance of `gpfdist` on your ETL host and then define your external table definition so that the host name of each NIC is declared in the `LOCATION` clause (see `CREATE EXTERNAL TABLE` in the *WarehousePG Reference Guide*). This allows network traffic between your WarehousePG segment hosts and your ETL host to use all NICs simultaneously.

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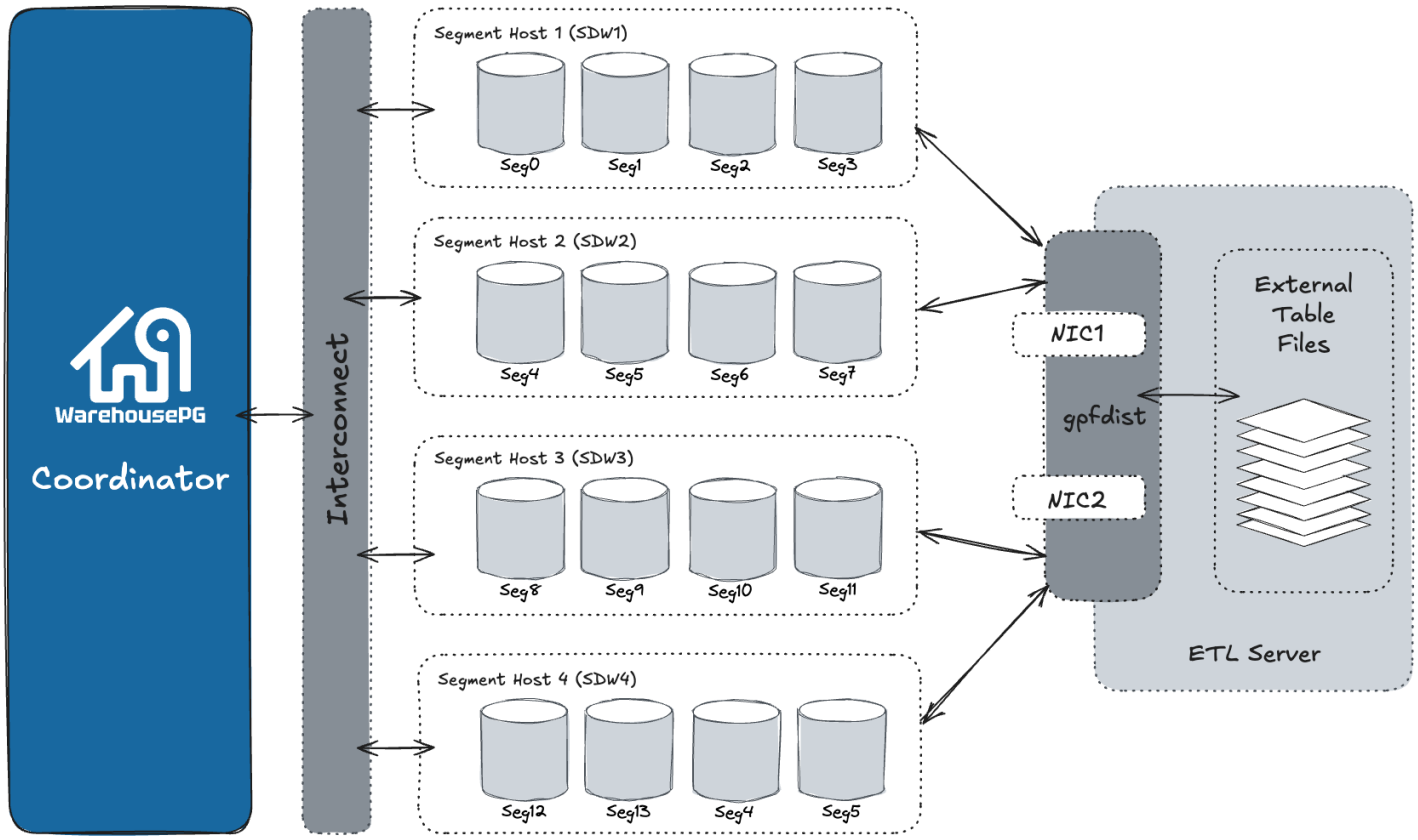
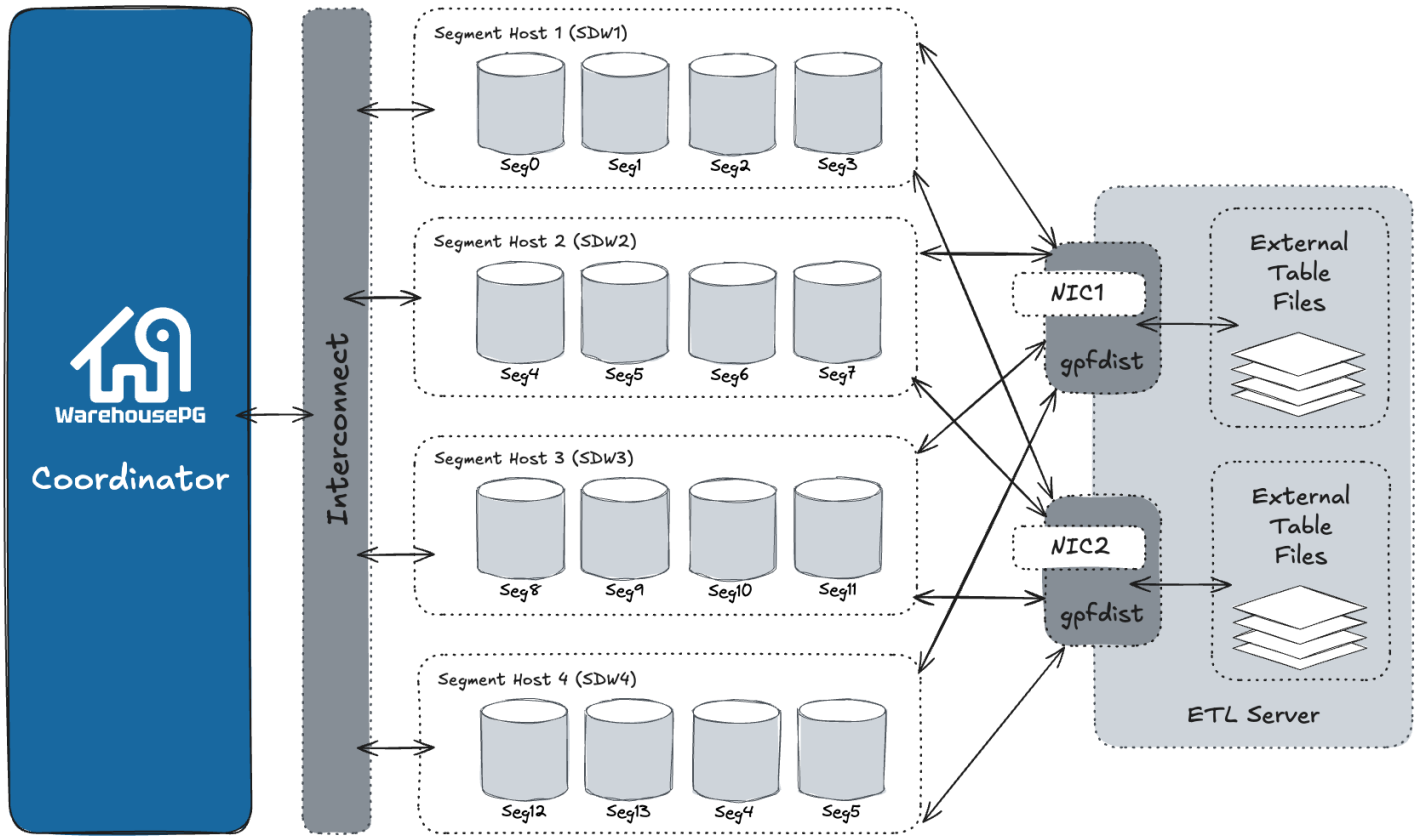


- Run multiple `gpfdist` instances on your ETL host and divide your external data files equally between each instance. For example, if you have an ETL system with two network interface cards (NICs), then you could run two `gpfdist` instances on that machine to maximize your load performance. You would then divide the external table data files evenly between the two `gpfdist` programs.



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4.1.2 About Management and Monitoring Utilities

WarehousePG provides standard command-line utilities for performing common monitoring and administration tasks.

WarehousePG command-line utilities are located in the $GPHOME/bin directory and are run on the coordinator host. WarehousePG provides utilities for the following administration tasks:

- Installing WarehousePG on an array
- Initializing WarehousePG
- Starting and stopping WarehousePG
- Adding or removing a host
- Expanding the array and redistributing tables among new segments
- Managing recovery for failed segment instances
- Managing failover and recovery for a failed coordinator instance
- Backing up and restoring a database (in parallel)
- Loading data in parallel
- Transferring data between WarehousePGs
- System state reporting

Parent topic: WarehousePG Concepts

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4.1.3 About Concurrency Control in WarehousePG

WarehousePG uses the PostgreSQL Multiversion Concurrency Control (MVCC) model to manage concurrent transactions for heap tables.

Concurrency control in a database management system allows concurrent queries to complete with correct results while ensuring the integrity of the database. Traditional databases use a two-phase locking protocol that prevents a transaction from modifying data that has been read by another concurrent transaction and prevents any concurrent transaction from reading or writing data that another transaction has updated. The locks required to coordinate transactions add contention to the database, reducing overall transaction throughput.

WarehousePG uses the PostgreSQL Multiversion Concurrency Control (MVCC) model to manage concurrency for heap tables. With MVCC, each query operates on a snapshot of the database when the query starts. While it runs, a query cannot see changes made by other concurrent transactions. This ensures that a query sees a consistent view of the database. Queries that read rows can never block waiting for transactions that write rows. Conversely, queries that write rows cannot be blocked by transactions that read rows. This allows much greater concurrency than traditional database systems that employ locks to coordinate access between transactions that read and write data.

> **Note** Append-optimized tables are managed with a different concurrency control model than the MVCC model discussed in this topic. They are intended for "write-once, read-many" applications that never, or only very rarely, perform row-level updates.

Snapshots

The MVCC model depends on the system's ability to manage multiple versions of data rows. A query operates on a snapshot of the database at the start of the query. A snapshot is the set of rows that are visible at the beginning of a statement or transaction. The snapshot ensures the query has a consistent and valid view of the database for the duration of its execution.

Each transaction is assigned a unique *transaction ID* (XID), an incrementing 32-bit value. When a new transaction starts, it is assigned the next XID. An SQL statement that is not enclosed in a transaction is treated as a single-statement transaction—the `BEGIN` and `COMMIT` are added implicitly. This is similar to autocommit in some database systems.

> **Note** WarehousePG assigns XID values only to transactions that involve DDL or DML operations, which are typically the only transactions that require an XID.

When a transaction inserts a row, the XID is saved with the row in the `xmin` system column. When a transaction deletes a row, the XID is saved in the `xmax` system column. Updating a row is treated as a delete and an insert, so the XID is saved to the `xmax` of the current row and the `xmin` of the newly inserted row. The `xmin` and `xmax` columns, together with the transaction completion status, specify a range of transactions for which the version of the row is visible. A transaction can see the effects of all transactions less than `xmin`, which are guaranteed to be committed, but it cannot see the effects of any transaction greater than or equal to `xmax`.

Multi-statement transactions must also record which command within a transaction inserted a row (`cmin`) or deleted a row (`cmax`) so that the transaction can see changes made by previous commands in the transaction. The command sequence is only relevant during the transaction, so the sequence is reset to 0 at the beginning of a transaction.

XID is a property of the database. Each segment database has its own XID sequence that cannot be compared to the XIDs of other segment databases. The coordinator coordinates distributed transactions with the segments using a cluster-wide *session ID number*, called `gp_session_id`. The segments maintain a mapping of distributed transaction IDs with their local XIDs. The coordinator coordinates distributed transactions across all of the segment with the two-phase commit protocol. If a transaction fails on any one segment, it is rolled back on all segments.

You can see the `xmin`, `xmax`, `cmin`, and `cmax` columns for any row with a `SELECT` statement:

```
SELECT xmin, xmax, cmin, cmax, * FROM <tablename>;
```

Because you run the `SELECT` command on the coordinator, the XIDs are the distributed transactions IDs. If you could run the command in an individual segment database, the `xmin` and `xmax` values would be the segment's local XIDs.

> **Note** WarehousePG distributes all of a replicated table's rows to every segment, so each row is duplicated on every segment. Each segment instance maintains its own values for the system columns `xmin`, `xmax`, `cmin`, and `cmax`, as well as for the `gp_segment_id` and `ctid` system columns. WarehousePG does not permit user queries to access these system columns for replicated tables because they have no single, unambiguous value to evaluate in a query.

Transaction ID Wraparound

The MVCC model uses transaction IDs (XIDs) to determine which rows are visible at the beginning of a query or transaction. The XID is a 32-bit value, so a database could theoretically run over four billion transactions before the value overflows and wraps to zero. However, WarehousePG uses *modulo 232* arithmetic with XIDs, which allows the transaction IDs to wrap around, much as a clock wraps at twelve o'clock. For any given XID, there could be about two billion past XIDs and two billion future XIDs. This works until a version of a row persists through about two billion transactions, when it suddenly appears to be a new row. To prevent this, WarehousePG has a special XID, called `FrozenXID`, which is always considered older than any regular XID it is compared with. The `xmin` of a row must be replaced with `FrozenXID` within two billion transactions, and this is one of the functions the `VACUUM` command performs.

Vacuuming the database at least every two billion transactions prevents XID wraparound. WarehousePG monitors the transaction ID and warns if a `VACUUM` operation is required.

A warning is issued when a significant portion of the transaction IDs are no longer available and before transaction ID wraparound occurs:

```
WARNING: database "<database_name>" must be vacuumed within <number_of_transactions> transactions
```

When the warning is issued, a `VACUUM` operation is required. If a `VACUUM` operation is not performed, WarehousePG stops creating transactions to avoid possible data loss when it reaches a limit prior to when transaction ID wraparound occurs and issues this error:

```
FATAL: database is not accepting commands to avoid wraparound data loss in database "<database_name>"
```

See Recovering from a Transaction ID Limit Error for the procedure to recover from this error.

The server configuration parameters `xid_warn_limit` and `xid_stop_limit` control when the warning and error are displayed. The `xid_warn_limit` parameter specifies the number of transaction IDs before the `xid_stop_limit` when the warning is issued. The `xid_stop_limit` parameter specifies the number of transaction IDs before wraparound would occur when the error is issued and new transactions cannot be created.

Transaction Isolation Levels

The SQL standard defines four levels of transaction isolation. The most strict is Serializable, which the standard defines as any concurrent execution of a set of Serializable transactions is guaranteed to produce the same effect as running them one at a time in some order. The other three levels are defined in terms of phenomena, resulting from interaction between concurrent transactions, which must not occur at each level. The standard notes that due to the definition of Serializable, none of these phenomena are possible at that level.

The phenomena which are prohibited at various levels are:

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- *dirty read* – A transaction reads data written by a concurrent uncommitted transaction.
- *non-repeatable read* – A transaction re-reads data that it has previously read and finds that the data has been modified by another transaction (that committed since the initial read).
- *phantom read* – A transaction re-executes a query returning a set of rows that satisfy a search condition and finds that the set of rows satisfying the condition has changed due to another recently-committed transaction.
- *serialization anomaly* - The result of successfully committing a group of transactions is inconsistent with all possible orderings of running those transactions one at a time.

The four transaction isolation levels defined in the SQL standard and the corresponding behaviors are described in the table below.

Isolation Level	Dirty Read	Non-Repeatable	Phantom Read	Serialization Anomoly
`READ UNCOMMITTED`	Allowed, but not in WarehousePG	Possible	Possible	Possible
`READ COMMITTED`	Impossible	Possible	Possible	Possible
`REPEATABLE READ`	Impossible	Impossible	Allowed, but not in WarehousePG	Possible
`SERIALIZABLE`	Impossible	Impossible	Impossible	Impossible

WarehousePG implements only two distinct transaction isolation levels, although you can request any of the four described levels. The WarehousePG `READ UNCOMMITTED` level behaves like `READ COMMITTED`, and the `SERIALIZABLE` level falls back to `REPEATABLE READ`.

The table also shows that WarehousePG's `REPEATABLE READ` implementation does not allow phantom reads. This is acceptable under the SQL standard because the standard specifies which anomalies must not occur at certain isolation levels; higher guarantees are acceptable.

The following sections detail the behavior of the available isolation levels.

Important: Some WarehousePG data types and functions have special rules regarding transactional behavior. In particular, changes made to a sequence (and therefore the counter of a column declared using `serial`) are immediately visible to all other transactions, and are not rolled back if the transaction that made the changes aborts.

Read Committed Isolation Level

The default isolation level in WarehousePG is `READ COMMITTED`. When a transaction uses this isolation level, a `SELECT` query (without a `FOR UPDATE/SHARE` clause) sees only data committed before the query began; it never sees either uncommitted data or changes committed during query execution by concurrent transactions. In effect, a `SELECT` query sees a snapshot of the database at the instant the query begins to run. However, `SELECT` does see the effects of previous updates executed within its own transaction, even though they are not yet committed. Also note that two successive `SELECT` commands can see different data, even though they are within a single transaction, if other transactions commit changes after the first `SELECT` starts and before the second `SELECT` starts.

`UPDATE`, `DELETE`, `SELECT FOR UPDATE`, and `SELECT FOR SHARE` commands behave the same as `SELECT` in terms of searching for target rows: they find only the target rows that were committed as of the command start time. However, such a target row might have already been updated (or deleted or locked) by another concurrent transaction by the time it is found. In this case, the would-be updater waits for the first updating transaction to commit or roll back (if it is still in progress). If the first updater rolls back, then its effects are negated and the second updater can proceed with updating the originally found row. If the first updater commits, the second updater will ignore the row if the first updater deleted it, otherwise it will attempt to apply its operation to the updated version of the row. The search condition of the command (the `WHERE` clause) is re-evaluated to see if the updated version of the row still matches the search condition. If so, the second updater proceeds with its operation using the updated version of the row. In the case of `SELECT FOR UPDATE` and `SELECT FOR SHARE`, this means the updated version of the row is locked and returned to the client.

`INSERT` with an `ON CONFLICT DO UPDATE` clause behaves similarly. In `READ COMMITTED` mode, each row proposed for insertion will either insert or update. Unless there are unrelated errors, one of those two outcomes is guaranteed. If a conflict originates in another transaction whose effects are not yet visible to the `INSERT`, the `UPDATE` clause will affect that row, even though possibly no version of that row is conventionally visible to the command.

`INSERT` with an `ON CONFLICT DO NOTHING` clause may have insertion not proceed for a row due to the outcome of another transaction whose effects are not visible to the `INSERT` snapshot. Again, this is only the case in `READ COMMITTED` mode.

Because of the above rules, it is possible for an updating command to see an inconsistent snapshot: it can see the effects of concurrent updating commands on the same rows it is trying to update, but it does not see effects of those commands on other rows in the database. This behavior makes `READ COMMITTED` mode unsuitable for commands that involve complex search conditions; however, it is just right for simpler cases. For example, consider updating bank balances with transactions like:

```
BEGIN;
UPDATE accounts SET balance = balance + 100.00 WHERE acctnum =
12345;
UPDATE accounts SET balance = balance - 100.00 WHERE acctnum =
7534;
COMMIT;
```

If two such transactions concurrently try to change the balance of account `12345`, we clearly want the second transaction to start with the updated version of the account's row. Because each command is affecting only a predetermined row, letting it access the updated version of the row does not create any troublesome inconsistency.

More complex usage may produce undesirable results in `READ COMMITTED` mode. For example, consider a `DELETE` command operating on data that is being both added and removed from its restriction criteria by another command; assume `website` is a two-row table with `website.hits` equaling `9` and `10`:

```
BEGIN;
UPDATE website SET hits = hits + 1;
-- run from another session:  DELETE FROM website WHERE hits =
10;
COMMIT;
```

The `DELETE` will have no effect even though there is a `website.hits = 10` row before and after the `UPDATE`. This occurs because the pre-update row value `9` is skipped, and when the `UPDATE` completes and `DELETE` obtains a lock, the new row value is no longer `10` but `11`, which no longer matches the criteria.

Because `READ COMMITTED` mode starts each command with a new snapshot that includes all transactions committed up to that instant, subsequent commands in the same transaction will see the effects of the committed concurrent transaction in any case. The point at issue above is whether or not a single command sees an absolutely consistent view of the database.

The partial transaction isolation provided by `READ COMMITTED` mode is adequate for many applications, and this mode is fast and simple to use; however, it is not sufficient for all cases. Applications that do complex queries and updates might require a more rigorously consistent view of the database than `READ COMMITTED` mode provides.

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Repeatable Read Isolation Level

The `REPEATABLE READ` isolation level only sees data committed before the transaction began; it never sees either uncommitted data or changes committed during transaction execution by concurrent transactions. (However, the query does see the effects of previous updates executed within its own transaction, even though they are not yet committed.) This is a stronger guarantee than is required by the SQL standard for this isolation level, and prevents all of the phenomena described in the table above. As mentioned previously, this is specifically allowed by the standard, which only describes the minimum protections each isolation level must provide.

The `REPEATABLE READ` isolation level is different from `READ COMMITTED` in that a query in a `REPEATABLE READ` transaction sees a snapshot as of the start of the first non-transaction-control statement in the transaction, not as of the start of the current statement within the transaction. Successive `SELECT` commands within a single transaction see the same data; they do not see changes made by other transactions that committed after their own transaction started.

Applications using this level must be prepared to retry transactions due to serialization failures.

`UPDATE`, `DELETE`, `SELECT FOR UPDATE`, and `SELECT FOR SHARE` commands behave the same as `SELECT` in terms of searching for target rows: they will only find target rows that were committed as of the transaction start time. However, such a target row might have already been updated (or deleted or locked) by another concurrent transaction by the time it is found. In this case, the `REPEATABLE READ` transaction will wait for the first updating transaction to commit or roll back (if it is still in progress). If the first updater rolls back, then its effects are negated and the `REPEATABLE READ` can proceed with updating the originally found row. But if the first updater commits (and actually updated or deleted the row, not just locked it), then WarehousePG rolls back the `REPEATABLE READ` transaction with the message:

```
ERROR:  could not serialize access due to concurrent update
```

because a `REPEATABLE READ` transaction cannot modify or lock rows changed by other transactions after the `REPEATABLE READ` transaction began.

When an application receives this error message, it should abort the current transaction and retry the whole transaction from the beginning. The second time through, the transaction will see the previously-committed change as part of its initial view of the database, so there is no logical conflict in using the new version of the row as the starting point for the new transaction's update.

Note that you may need to retry only updating transactions; read-only transactions will never have serialization conflicts.

The `REPEATABLE READ` mode provides a rigorous guarantee that each transaction sees a completely stable view of the database. However, this view will not necessarily always be consistent with some serial (one at a time) execution of concurrent transactions of the same level. For example, even a read-only transaction at this level may see a control record updated to show that a batch has been completed but not see one of the detail records which is logically part of the batch because it read an earlier revision of the control record. Attempts to enforce business rules by transactions running at this isolation level are not likely to work correctly without careful use of explicit locks to block conflicting transactions.

Serializable Isolation Level

The `SERIALIZABLE` level, which WarehousePG does not fully support, guarantees that a set of transactions run concurrently produces the same result as if the transactions ran sequentially one after the other. If `SERIALIZABLE` is specified, WarehousePG falls back to `REPEATABLE READ`. The MVCC Snapshot Isolation (SI) model prevents dirty reads, non-repeatable reads, and phantom reads without expensive locking, but there are other interactions that can occur between some `SERIALIZABLE` transactions in WarehousePG that prevent them from being truly serializable. These anomalies can often be attributed to the fact that WarehousePG does not perform *predicate locking*, which means that a write in one transaction can affect the result of a previous read in another concurrent transaction.

About Setting the Transaction Isolation Level

The default transaction isolation level for WarehousePG is specified by the default_transaction_isolation server configuration parameter, and is initially `READ COMMITTED`.

When you set `default_transaction_isolation` in a session, you specify the default transaction isolation level for all transactions in the session.

To set the isolation level for the current transaction, you can use the SET TRANSACTION SQL command. Be sure to set the isolation level before any `SELECT`, `INSERT`, `DELETE`, `UPDATE`, or `COPY` statement:

```
BEGIN;
SET TRANSACTION ISOLATION LEVEL REPEATABLE READ;
...
COMMIT;
```

You can also specify the isolation mode in a `BEGIN` statement:

```
BEGIN TRANSACTION ISOLATION LEVEL REPEATABLE READ;
```

Removing Dead Rows from Tables

Updating or deleting a row leaves an expired version of the row in the table. When an expired row is no longer referenced by any active transactions, it can be removed and the space it occupied can be reused. The `VACUUM` command marks the space used by expired rows for reuse.

When expired rows accumulate in a table, the disk files must be extended to accommodate new rows. Performance degrades due to the increased disk I/O required to run queries. This condition is called *bloat* and it should be managed by regularly vacuuming tables.

The `VACUUM` command (without `FULL`) can run concurrently with other queries. It marks the space previously used by the expired rows as free, and updates the free space map. When WarehousePG later needs space for new rows, it first consults the table's free space map to find pages with available space. If none are found, new pages will be appended to the file.

`VACUUM` (without `FULL`) does not consolidate pages or reduce the size of the table on disk. The space it recovers is only available through the free space map. To prevent disk files from growing, it is important to run `VACUUM` often enough. The frequency of required `VACUUM` runs depends on the frequency of updates and deletes in the table (inserts only ever add new rows). Heavily updated tables might require several `VACUUM` runs per day, to ensure that the available free space can be found through the free space map. It is also important to run `VACUUM` after running a transaction that updates or deletes a large number of rows.

The `VACUUM FULL` command rewrites the table without expired rows, reducing the table to its minimum size. Every page in the table is checked, and visible rows are moved up into pages which are not yet fully packed. Empty pages are discarded. The table is locked until `VACUUM FULL` completes. This is very expensive compared to the regular `VACUUM` command, and can be avoided or postponed by vacuuming regularly. It is best to run `VACUUM FULL` during a maintenance period. An alternative to `VACUUM FULL` is to recreate the table with a `CREATE TABLE AS` statement and then drop the old table.

You can run `VACUUM VERBOSE tablename` to get a report, by segment, of the number of dead rows removed, the number of pages affected, and the number of pages with usable free space.

Query the `pg_class` system table to find out how many pages a table is using across all segments. Be sure to `ANALYZE` the table first to get accurate data.

```
SELECT relname, relpages, reltuples FROM pg_class WHERE relname='<tablename>';
```

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Another useful tool is the `gp_bloat_diag` view in the `gp_toolkit` schema, which identifies bloat in tables by comparing the actual number of pages used by a table to the expected number. See "The gp_toolkit Administrative Schema" in the *WarehousePG Reference Guide* for more about `gp_bloat_diag`.

- **Example of Managing Transaction IDs**

Parent topic: WarehousePG Concepts

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4.1.3.1 Example of Managing Transaction IDs

For WarehousePG, the transaction ID (XID) value an incrementing 32-bit (2^{32}) value. The maximum unsigned 32-bit value is 4,294,967,295, or about four billion. The XID values restart at 3 after the maximum is reached. WarehousePG handles the limit of XID values with two features:

- Calculations on XID values using modulo-2^{32} arithmetic that allow WarehousePG to reuse XID values. The modulo calculations determine the order of transactions, whether one transaction has occurred before or after another, based on the XID.

  Every XID value can have up to two billion (2^{31}) XID values that are considered previous transactions and two billion (231 -1) XID values that are considered newer transactions. The XID values can be considered a circular set of values with no endpoint similar to a 24 hour clock.

  Using the WarehousePG modulo calculations, as long as two XIDs are within 2^{31} transactions of each other, comparing them yields the correct result.

- A frozen XID value that WarehousePG uses as the XID for current (visible) data rows. Setting a row's XID to the frozen XID performs two functions.

  - When WarehousePG compares XIDs using the modulo calculations, the frozen XID is always smaller, earlier, when compared to any other XID. If a row's XID is not set to the frozen XID and 2^{31} new transactions are run, the row appears to be run in the future based on the modulo calculation.
  - When the row's XID is set to the frozen XID, the original XID can be used, without duplicating the XID. This keeps the number of data rows on disk with assigned XIDs below (2^{32}).

> **Note** WarehousePG assigns XID values only to transactions that involve DDL or DML operations, which are typically the only transactions that require an XID.

Parent topic: About Concurrency Control in WarehousePG

Simple MVCC Example

This is a simple example of the concepts of a MVCC database and how it manages data and transactions with transaction IDs. This simple MVCC database example consists of a single table:

- The table is a simple table with 2 columns and 4 rows of data.
- The valid transaction ID (XID) values are from 0 up to 9, after 9 the XID restarts at 0.
- The frozen XID is -2. This is different than the WarehousePG frozen XID.
- Transactions are performed on a single row.
- Only insert and update operations are performed.
- All updated rows remain on disk, no operations are performed to remove obsolete rows.

The example only updates the amount values. No other changes to the table.

The example shows these concepts.

- How transaction IDs are used to manage multiple, simultaneous transactions on a table.
- How transaction IDs are managed with the frozen XID
- How the modulo calculation determines the order of transactions based on transaction IDs

Managing Simultaneous Transactions

This table is the initial table data on disk with no updates. The table contains two database columns for transaction IDs, `xmin` (transaction that created the row) and `xmax` (transaction that updated the row). In the table, changes are added, in order, to the bottom of the table.

item	amount	xmin	xmax
widget	100	0	null
giblet	200	1	null
sprocket	300	2	null
gizmo	400	3	null

The next table shows the table data on disk after some updates on the amount values have been performed.

- xid = 4: `update tbl set amount=208 where item = 'widget'`
- xid = 5: `update tbl set amount=133 where item = 'sprocket'`
- xid = 6: `update tbl set amount=16 where item = 'widget'`

In the next table, the bold items are the current rows for the table. The other rows are obsolete rows, table data that on disk but is no longer current. Using the xmax value, you can determine the current rows of the table by selecting the rows with `null` value. WarehousePG uses a slightly different method to determine current table rows.

item	amount	xmin	xmax
widget	100	0	4
giblet	**200**	1	**null**
sprocket	300	2	5
gizmo	**400**	3	**null**
widget	208	4	6
sprocket	**133**	5	**null**
widget	**16**	6	**null**

The simple MVCC database works with XID values to determine the state of the table. For example, both these independent transactions run concurrently.

- `UPDATE` command changes the sprocket amount value to `133` (xmin value `5`)
- `SELECT` command returns the value of sprocket.

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During the `UPDATE` transaction, the database returns the value of sprocket `300`, until the `UPDATE` transaction completes.

Managing XIDs and the Frozen XID

For this simple example, the database is close to running out of available XID values. When WarehousePG is close to running out of available XID values, WarehousePG takes these actions.

- WarehousePG issues a warning stating that the database is running out of XID values.

  ```
  WARNING: database "<database_name>" must be vacuumed within <number_of_transactions> transactions
  ```

- Before the last XID is assigned, WarehousePG stops accepting transactions to prevent assigning an XID value twice and issues this message.

  ```
  FATAL: database is not accepting commands to avoid wraparound data loss in database "<database_name>"
  ```

To manage transaction IDs and table data that is stored on disk, WarehousePG provides the `VACUUM` command.

- A `VACUUM` operation frees up XID values so that a table can have more than 10 rows by changing the xmin values to the frozen XID.
- A `VACUUM` operation manages obsolete or deleted table rows on disk. This database's `VACUUM` command changes the XID values `obsolete` to indicate obsolete rows. A WarehousePG `VACUUM` operation, without the `FULL` option, deletes the data opportunistically to remove rows on disk with minimal impact to performance and data availability.

For the example table, a `VACUUM` operation has been performed on the table. The command updated table data on disk. This version of the `VACUUM` command performs slightly differently than the WarehousePG command, but the concepts are the same.

- For the widget and sprocket rows on disk that are no longer current, the rows have been marked as `obsolete`.

- For the giblet and gizmo rows that are current, the xmin has been changed to the frozen XID.

  The values are still current table values (the row's xmax value is `null`). However, the table row is visible to all transactions because the xmin value is frozen XID value that is older than all other XID values when modulo calculations are performed.

After the `VACUUM` operation, the XID values `0`, `1`, `2`, and `3` available for use.

item	amount	xmin	xmax
widget	100	obsolete	obsolete
giblet	**200**	-2	**null**
sprocket	300	obsolete	obsolete
gizmo	**400**	-2	**null**
widget	208	4	6
sprocket	**133**	5	**null**
widget	**16**	6	**null**

When a row disk with the xmin value of `-2` is updated, the xmax value is replaced with the transaction XID as usual, and the row on disk is considered obsolete after any concurrent transactions that access the row have completed.

Obsolete rows can be deleted from disk. For WarehousePG, the `VACUUM` command, with `FULL` option, does more extensive processing to reclaim disk space.

Example of XID Modulo Calculations

The next table shows the table data on disk after more `UPDATE` transactions. The XID values have rolled over and start over at `0`. No additional `VACUUM` operations have been performed.

item	amount	xmin	xmax
widget	100	obsolete	obsolete
giblet	200	-2	1
sprocket	300	obsolete	obsolete
gizmo	400	-2	9
widget	208	4	6
sprocket	**133**	5	**null**
widget	16	6	7
widget	**222**	7	**null**
giblet	233	8	0
gizmo	**18**	9	**null**
giblet	88	0	1
giblet	**44**	1	**null**

When performing the modulo calculations that compare XIDs, WarehousePG, considers the XIDs of the rows and the current range of available XIDs to determine if XID wrapping has occurred between row XIDs.

For the example table XID wrapping has occurred. The XID `1` for giblet row is a later transaction than the XID `7` for widget row based on the modulo calculations for XID values even though the XID value `7` is larger than `1`.

For the widget and sprocket rows, XID wrapping has not occurred and XID `7` is a later transaction than XID `5`.

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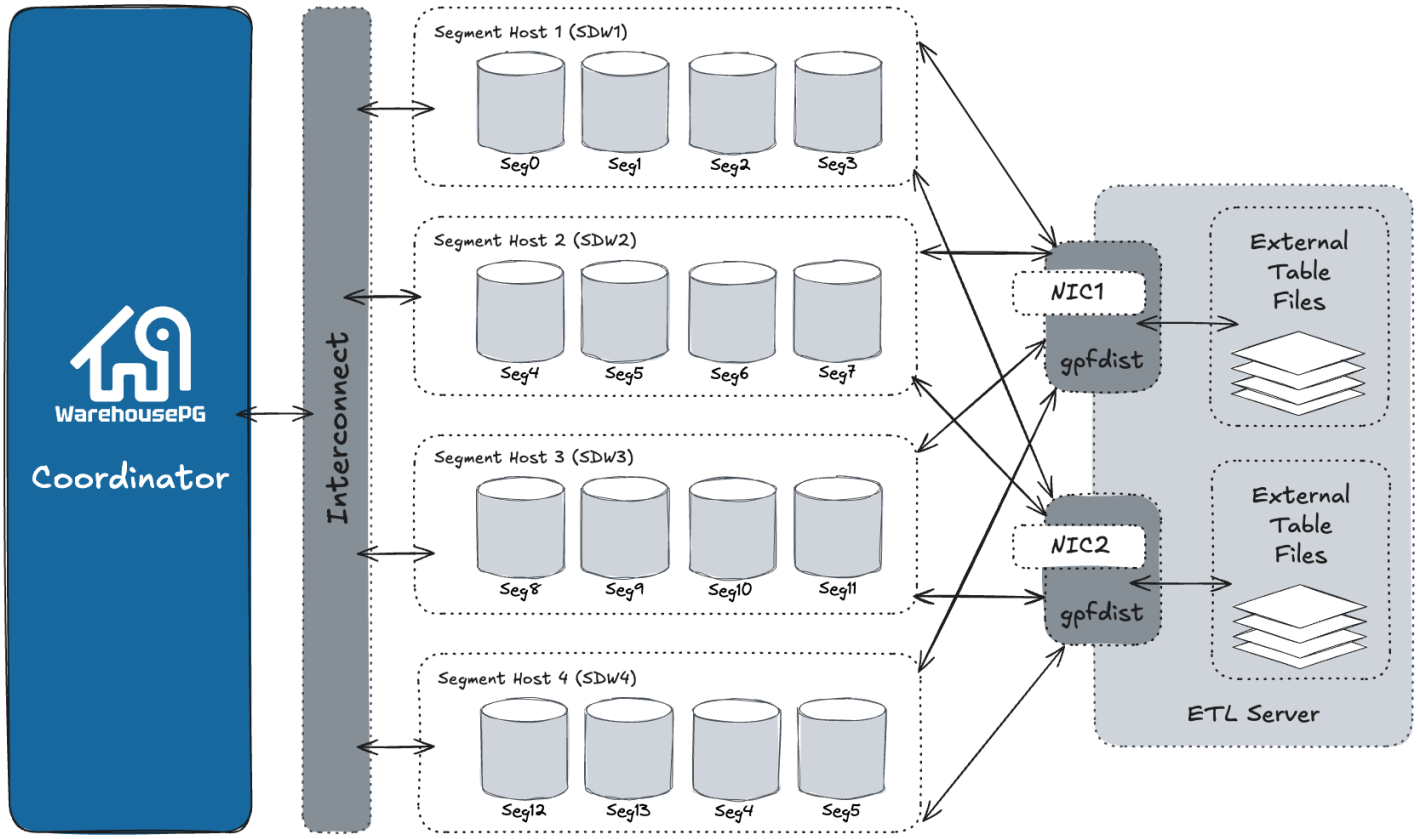
4.1.4 About Parallel Data Loading

This topic provides a short introduction to WarehousePG data loading features.

In a large scale, multi-terabyte data warehouse, large amounts of data must be loaded within a relatively small maintenance window. WarehousePG supports fast, parallel data loading with its external tables feature. Administrators can also load external tables in single row error isolation mode to filter bad rows into a separate error log while continuing to load properly formatted rows. Administrators can specify an error threshold for a load operation to control how many improperly formatted rows cause WarehousePG to cancel the load operation.

By using external tables in conjunction with WarehousePG's parallel file server (`gpfdist`), administrators can achieve maximum parallelism and load bandwidth from their WarehousePG cluster.



Another WarehousePG utility, `gpload` , runs a load task that you specify in a YAML-formatted control file. You describe the source data locations, format, transformations required, participating hosts, database destinations, and other particulars in the control file and `gpload` runs the load. This allows you to describe a complex task and run it in a controlled, repeatable fashion.

Parent topic: WarehousePG Concepts

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4.1.5 About Redundancy and Failover in WarehousePG

This topic provides a high-level overview of WarehousePG high availability features.

You can deploy WarehousePG without a single point of failure by mirroring components. The following sections describe the strategies for mirroring the main components of a WarehousePG cluster. For a more detailed overview of WarehousePG high availability features, see Overview of WarehousePG High Availability.

> **Important** When data loss is not acceptable for a WarehousePG cluster, WarehousePG coordinator and segment mirroring is recommended. If mirroring is not enabled then WarehousePG stores only one copy of the data, so the underlying storage media provides the only guarantee for data availability and correctness in the event of a hardware failure.

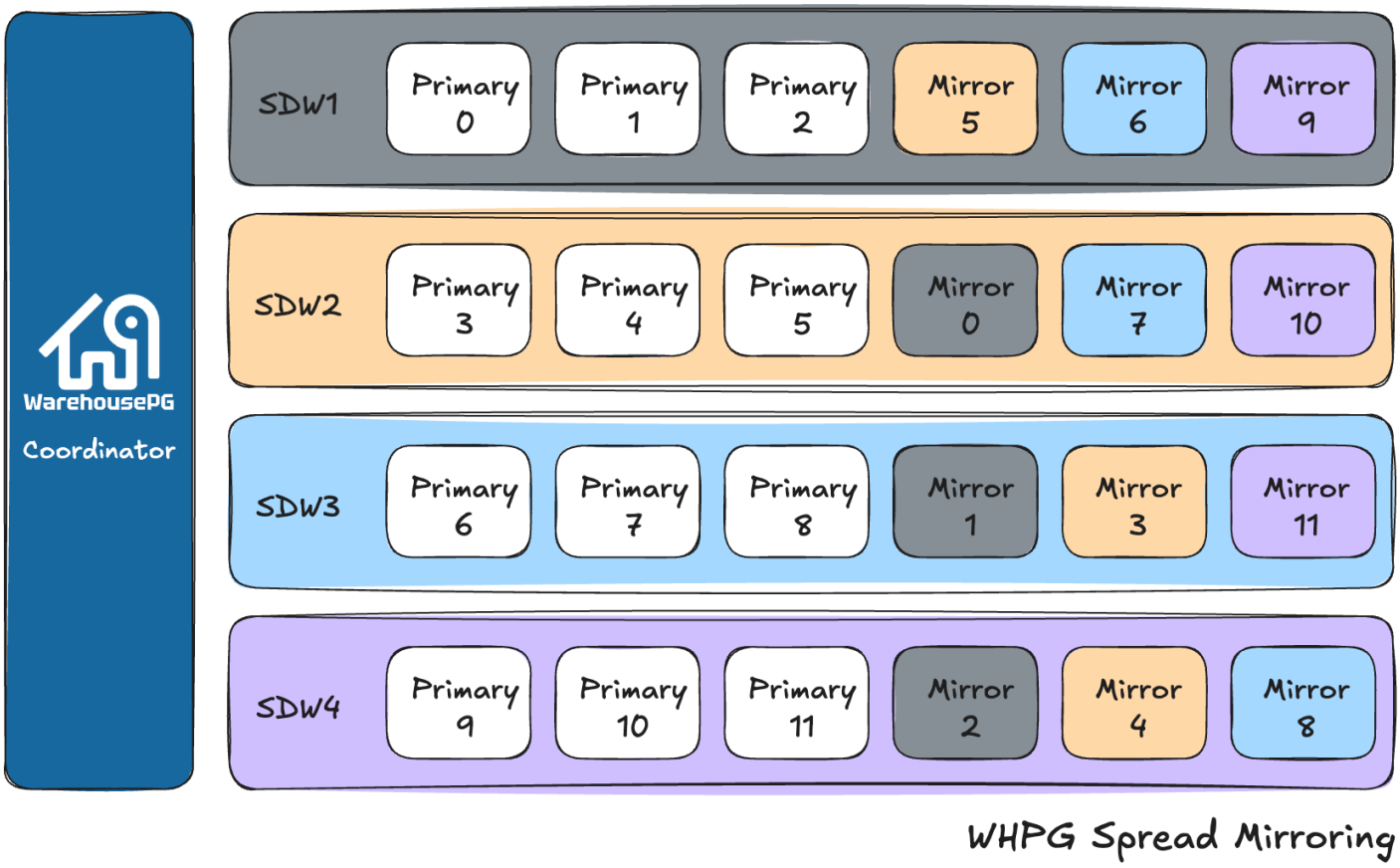
About Segment Mirroring

When you deploy your WarehousePG cluster, you can configure *mirror* segment instances. Mirror segments allow database queries to fail over to a backup segment if the primary segment becomes unavailable. The mirror segment is kept current by a transaction log replication process, which synchronizes the data between the primary and mirror instances. Mirroring is strongly recommended for production systems and required for WarehousePG support.

As a best practice, the secondary (mirror) segment instance must always reside on a different host than its primary segment instance to protect against a single host failure. In virtualized environments, the secondary (mirror) segment must always reside on a different storage system than the primary. Mirror segments can be arranged over the remaining hosts in the cluster in configurations designed to maximize availability, or minimize the performance degradation when hosts or multiple primary segments fail.

Two standard mirroring configurations are available when you initialize or expand a WarehousePG cluster. The default configuration, called *group mirroring*, places all the mirrors for a host's primary segments on one other host in the cluster. The other standard configuration, *spread mirroring*, can be selected with a command-line option. Spread mirroring spreads each host's mirrors over the remaining hosts and requires that there are more hosts in the cluster than primary segments per host.

This figure shows how table data is distributed across segments when spread mirroring is configured.



Segment Failover and Recovery

When segment mirroring is enabled in a WarehousePG cluster, the system will automatically fail over to the *mirror segment* instance if a *primary segment* instance becomes unavailable. A WarehousePG cluster can remain operational if a segment instance or host goes down as long as all the data is available on the remaining active segment instances.

If the coordinator cannot connect to a segment instance, it marks that segment instance as down in the WarehousePG cluster catalog and brings up the mirror segment in its place. A failed segment instance will remain out of operation until an administrator takes steps to bring that segment back online. An administrator can recover a failed segment while the system is up and running. The recovery process copies over only the changes that were missed while the segment was out of operation.

If you do not have mirroring enabled, the system will automatically shut down if a segment instance becomes invalid. You must recover all failed segments before operations can continue.

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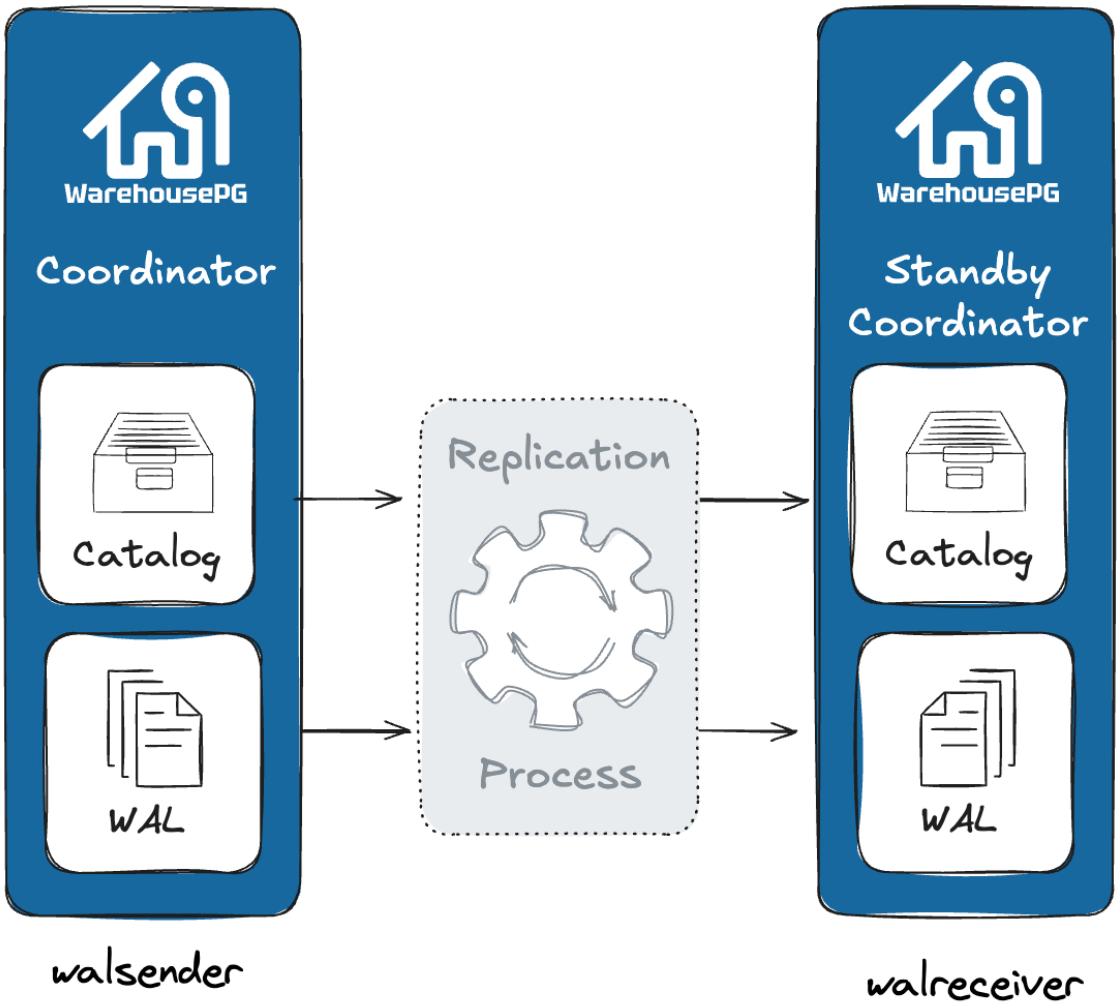
About Coordinator Mirroring

You can also optionally deploy a backup or mirror of the coordinator instance on a separate host from the coordinator host. The backup coordinator instance (the *standby coordinator*) serves as a *warm standby* in the event that the primary coordinator host becomes non-operational. The standby coordinator is kept current by a transaction log replication process, which synchronizes the data between the primary and standby coordinator.

If the primary coordinator fails, the log replication process stops, and the standby coordinator can be activated in its place. The switchover does not happen automatically, but must be triggered externally. Upon activation of the standby coordinator, the replicated logs are used to reconstruct the state of the coordinator host at the time of the last successfully committed transaction. The activated standby coordinator effectively becomes the WarehousePG coordinator, accepting client connections on the coordinator port (which must be set to the same port number on the coordinator host and the backup coordinator host).

Since the coordinator does not contain any user data, only the system catalog tables need to be synchronized between the primary and backup copies. When these tables are updated, changes are automatically copied over to the standby coordinator to ensure synchronization with the primary coordinator.



About Interconnect Redundancy

The *interconnect* refers to the inter-process communication between the segments and the network infrastructure on which this communication relies. You can achieve a highly available interconnect using by deploying dual Gigabit Ethernet switches on your network and redundant Gigabit connections to the WarehousePG host (coordinator and segment) servers. For performance reasons, 10-Gb Ethernet, or faster, is recommended.

Parent topic: WarehousePG Concepts

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4.1.6 About Database Statistics in WarehousePG

An overview of statistics gathered by the ANALYZE command in WarehousePG.

Statistics are metadata that describe the data stored in the database. The query optimizer needs up-to-date statistics to choose the best execution plan for a query. For example, if a query joins two tables and one of them must be broadcast to all segments, the optimizer can choose the smaller of the two tables to minimize network traffic.

The statistics used by the optimizer are calculated and saved in the system catalog by the `ANALYZE` command. There are three ways to initiate an analyze operation:

- You can run the `ANALYZE` command directly.
- You can run the `analyzedb` management utility outside of the database, at the command line.
- An automatic analyze operation can be triggered when DML operations are performed on tables that have no statistics or when a DML operation modifies a number of rows greater than a specified threshold.

These methods are described in the following sections. The `VACUUM ANALYZE` command is another way to initiate an analyze operation, but its use is discouraged because vacuum and analyze are different operations with different purposes.

Calculating statistics consumes time and resources, so WarehousePG produces estimates by calculating statistics on samples of large tables. In most cases, the default settings provide the information needed to generate correct execution plans for queries. If the statistics produced are not producing optimal query execution plans, the administrator can tune configuration parameters to produce more accurate statistics by increasing the sample size or the granularity of statistics saved in the system catalog. Producing more accurate statistics has CPU and storage costs and may not produce better plans, so it is important to view explain plans and test query performance to ensure that the additional statistics-related costs result in better query performance.

Parent topic: WarehousePG Concepts

System Statistics

Table Size

The query planner seeks to minimize the disk I/O and network traffic required to run a query, using estimates of the number of rows that must be processed and the number of disk pages the query must access. The data from which these estimates are derived are the `pg_class` system table columns `reltuples` and `relpages`, which contain the number of rows and pages at the time a `VACUUM` or `ANALYZE` command was last run. As rows are added or deleted, the numbers become less accurate. However, an accurate count of disk pages is always available from the operating system, so as long as the ratio of `reltuples` to `relpages` does not change significantly, the optimizer can produce an estimate of the number of rows that is sufficiently accurate to choose the correct query execution plan.

When the `reltuples` column differs significantly from the row count returned by `SELECT COUNT(*)`, an analyze should be performed to update the statistics.

When a `REINDEX` command finishes recreating an index, the `relpages` and `reltuples` columns are set to zero. The `ANALYZE` command should be run on the base table to update these columns.

The pg_statistic System Table and pg_stats View

The `pg_statistic` system table holds the results of the last `ANALYZE` operation on each database table. There is a row for each column of every table. It has the following columns:

starelid The object ID of the table or index the column belongs to.

staattnum The number of the described column, beginning with 1.

stainherit If true, the statistics include inheritance child columns, not just the values in the specified relation.

stanullfrac The fraction of the column's entries that are null.

stawidth The average stored width, in bytes, of non-null entries.

stadistinct A positive number is an estimate of the number of distinct values in the column; the number is not expected to vary with the number of rows. A negative value is the number of distinct values divided by the number of rows, that is, the ratio of rows with distinct values for the column, negated. This form is used when the number of distinct values increases with the number of rows. A unique column, for example, has an `n_distinct` value of -1.0. Columns with an average width greater than 1024 are considered unique.

stakind*N* A code number indicating the kind of statistics stored in the *N*th slot of the `pg_statistic` row.

staop*N* An operator used to derive the statistics stored in the *N*th slot. For example, a histogram slot would show the < operator that defines the sort order of the data.

stanumbers*N* float4 array containing numerical statistics of the appropriate kind for the *N*th slot, or `NULL` if the slot kind does not involve numerical values.

stavalues*N* Column data values of the appropriate kind for the *N*th slot, or `NULL` if the slot kind does not store any data values. Each array's element values are actually of the specific column's data type, so there is no way to define these columns' types more specifically than *anyarray*.

The statistics collected for a column vary for different data types, so the `pg_statistic` table stores statistics that are appropriate for the data type in four *slots*, consisting of four columns per slot. For example, the first slot, which normally contains the most common values for a column, consists of the columns `stakind1`, `staop1`, `stanumbers1`, and `stavalues1`.

The `stakindN` columns each contain a numeric code to describe the type of statistics stored in their slot. The `stakind` code numbers from 1 to 99 are reserved for core PostgreSQL data types. WarehousePG uses code numbers 1, 2, 3, 4, 5, and 99. A value of 0 means the slot is unused. The following table describes the kinds of statistics stored for the three codes.

Table 1. Contents of pg_statistic "slots"

stakind Code	Description
1	*Most CommonValues (MCV) Slot* • `staop` contains the object ID of the "=" operator, used to decide whether values are the same or not. • `stavalues` contains an array of the *K* most common non-null values appearing in the column. • `stanumbers` contains the frequencies (fractions of total row count) of the values in the `stavalues` array. The values are ordered in decreasing frequency. Since the arrays are variable-size, *K* can be chosen by the statistics collector. Values must occur more than once to be added to the `stavalues` array; a unique column has no MCV slot.

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stakind Code	Description
2	*Histogram Slot* – describes the distribution of scalar data. • `staop` is the object ID of the "<" operator, which describes the sort ordering. • `stavalues` contains *M* (where *M*>=2) non-null values that divide the non-null column data values into *M*-1 bins of approximately equal population. The first `stavalues` item is the minimum value and the last is the maximum value. • `stanumbers` is not used and should be `NULL` . If a Most Common Values slot is also provided, then the histogram describes the data distribution after removing the values listed in the MCV array. (It is a *compressed histogram* in the technical parlance). This allows a more accurate representation of the distribution of a column with some very common values. In a column with only a few distinct values, it is possible that the MCV list describes the entire data population; in this case the histogram reduces to empty and should be omitted.
3	*Correlation Slot* – describes the correlation between the physical order of table tuples and the ordering of data values of this column. • `staop` is the object ID of the "<" operator. As with the histogram, more than one entry could theoretically appear. • `stavalues` is not used and should be `NULL` . • `stanumbers` contains a single entry, the correlation coefficient between the sequence of data values and the sequence of their actual tuple positions. The coefficient ranges from +1 to -1.
4	*Most Common Elements Slot* - is similar to a Most Common Values (MCV) Slot, except that it stores the most common non-null *elements* of the column values. This is useful when the column datatype is an array or some other type with identifiable elements (for instance, `tsvector`). • `staop` contains the equality operator appropriate to the element type. • `stavalues` contains the most common element values. • `stanumbers` contains common element frequencies. Frequencies are measured as the fraction of non-null rows the element value appears in, not the frequency of all rows. Also, the values are sorted into the element type's default order (to support binary search for a particular value). Since this puts the minimum and maximum frequencies at unpredictable spots in `stanumbers` , there are two extra members of `stanumbers` that hold copies of the minimum and maximum frequencies. Optionally, there can be a third extra member that holds the frequency of null elements (the frequency is expressed in the same terms: the fraction of non-null rows that contain at least one null element). If this member is omitted, the column is presumed to contain no `NULL` elements. Note: For `tsvector` columns, the `stavalues` elements are of type `text` , even though their representation within `tsvector` is not exactly `text` .
5	*Distinct Elements Count Histogram Slot* - describes the distribution of the number of distinct element values present in each row of an array-type column. Only non-null rows are considered, and only non-null elements. • `staop` contains the equality operator appropriate to the element type. • `stavalues` is not used and should be `NULL` . • `stanumbers` contains information about distinct elements. The last member of `stanumbers` is the average count of distinct element values over all non-null rows. The preceding *M* (where *M* >=2) members form a histogram that divides the population of distinct-elements counts into *M*-1 bins of approximately equal population. The first of these is the minimum observed count, and the last the maximum.
99	*Hyperloglog Slot* - for leaf partitions of a partitioned table, stores the `hyperloglog_counter` created for the sampled data. The `hyperloglog_counter` data structure is converted into a `bytea` and stored in a `stavalues5` slot of the `pg_statistic` catalog table.

The `pg_stats` view presents the contents of `pg_statistic` in a friendlier format. The `pg_stats` view has the following columns:

schemaname The name of the schema containing the table.

tablename The name of the table.

attname The name of the column this row describes.

inherited If true, the statistics include inheritance child columns.

null_frac The fraction of column entries that are null.

avg_width The average storage width in bytes of the column's entries, calculated as `avg(pg_column_size(column_name))` .

n_distinct A positive number is an estimate of the number of distinct values in the column; the number is not expected to vary with the number of rows. A negative value is the number of distinct values divided by the number of rows, that is, the ratio of rows with distinct values for the column, negated. This form is used when the number of distinct values increases with the number of rows. A unique column, for example, has an `n_distinct` value of -1.0. Columns with an average width greater than 1024 are considered unique.

most_common_vals An array containing the most common values in the column, or null if no values seem to be more common. If the `n_distinct` column is -1, `most_common_vals` is null. The length of the array is the lesser of the number of actual distinct column values or the value of the `default_statistics_target` configuration parameter. The number of values can be overridden for a column using `ALTER TABLE table SET COLUMN column SET STATISTICS N` .

most_common_freqs An array containing the frequencies of the values in the `most_common_vals` array. This is the number of occurrences of the value divided by the total number of rows. The array is the same length as the `most_common_vals` array. It is null if `most_common_vals` is null.

histogram_bounds An array of values that divide the column values into groups of approximately the same size. A histogram can be defined only if there is a `max()` aggregate function for the column. The number of groups in the histogram is the same as the `most_common_vals` array size.

correlation WarehousePG computes correlation statistics for both heap and AO/AOCO tables, but the Postgres-based planner uses these statistics only for heap tables.

most_common_elems An array that contains the most common element values.

most_common_elem_freqs An array that contains common element frequencies.

elem_count_histogram An array that describes the distribution of the number of distinct element values present in each row of an array-type column.

Newly created tables and indexes have no statistics. You can check for tables with missing statistics using the `gp_stats_missing` view, which is in the `gp_toolkit` schema:

```
SELECT * from gp_toolkit.gp_stats_missing;
```

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Sampling

When calculating statistics for large tables, WarehousePG creates a smaller table by sampling the base table. If the table is partitioned, samples are taken from all partitions.

Updating Statistics

Running `ANALYZE` with no arguments updates statistics for all tables in the database. This could take a very long time, so it is better to analyze tables selectively after data has changed. You can also analyze a subset of the columns in a table, for example columns used in joins, `WHERE` clauses, `SORT` clauses, `GROUP BY` clauses, or `HAVING` clauses.

Analyzing a severely bloated table can generate poor statistics if the sample contains empty pages, so it is good practice to vacuum a bloated table before analyzing it.

See the *SQL Command Reference* in the *WarehousePG Reference Guide* for details of running the `ANALYZE` command.

Refer to the *WarehousePG Management Utility Reference* for details of running the `analyzedb` command.

Analyzing Partitioned Tables

When the `ANALYZE` command is run on a partitioned table, it analyzes each leaf partition, one at a time. You can run `ANALYZE` on just new or changed partitioned tables to avoid analyzing partitions that have not changed.

The `analyzedb` command-line utility skips unchanged partitions automatically. It also runs concurrent sessions so it can analyze several partitions concurrently. It runs five sessions by default, but the number of sessions can be set from 1 to 10 with the `-p` command-line option. Each time `analyzedb` runs, it saves state information for append-optimized tables and partitions in the `db_analyze` directory in the coordinator data directory. The next time it runs, `analyzedb` compares the current state of each table with the saved state and skips analyzing a table or partition if it is unchanged. Heap tables are always analyzed.

If GPORCA is enabled (the default), you also need to run `ANALYZE` or `ANALYZE ROOTPARTITION` on the root partitioned table (not a leaf partition) to refresh the root partition statistics. GPORCA requires statistics at the root level for partitioned tables. The Postgres-based planner does not use these statistics.

The time to analyze a partitioned table is similar to the time to analyze a non-partitioned table with the same data. When all the leaf partitions have statistics, performing `ANALYZE ROOTPARTITION` to generate root partition statistics should be quick (a few seconds depending on the number of partitions and table columns). If some of the leaf partitions do not have statistics, then all the table data is sampled to generate root partition statistics. Sampling table data takes longer and results in lower quality root partition statistics.

The WarehousePG server configuration parameter optimizer_analyze_root_partition affects when statistics are collected on the root partitioned table. If the parameter is `on` (the default), the `ROOTPARTITION` keyword is not required to collect statistics on the root partition when you run `ANALYZE`. Root partition statistics are collected when you run `ANALYZE` on the root partition, or when you run `ANALYZE` on a leaf partition of the partitioned table and the other leaf partitions have statistics. If the parameter is `off`, you must run `ANALYZE ROOTPARTITION` to collect root partition statistics.

If you do not intend to run queries on partitioned tables with GPORCA (setting the server configuration parameter optimizer to `off`), you can also set the server configuration parameter `optimizer_analyze_root_partition` to `off` to limit when `ANALYZE` updates the root partition statistics.

Configuring Statistics

There are several options for configuring WarehousePG statistics collection.

Statistics Target

The statistics target is the size of the `most_common_vals`, `most_common_freqs`, and `histogram_bounds` arrays for an individual column. By default, the target is 25. The default target can be changed by setting a server configuration parameter and the target can be set for any column using the `ALTER TABLE` command. Larger values increase the time needed to do `ANALYZE`, but may improve the quality of the Postgres-based planner estimates.

Set the system default statistics target to a different value by setting the `default_statistics_target` server configuration parameter. The default value is usually sufficient, and you should only raise or lower it if your tests demonstrate that query plans improve with the new target. For example, to raise the default statistics target from 100 to 150 you can use the `gpconfig` utility:

```
gpconfig -c default_statistics_target -v 150
```

The statistics target for individual columns can be set with the `ALTER TABLE` command. For example, some queries can be improved by increasing the target for certain columns, especially columns that have irregular distributions. You can set the target to zero for columns that never contribute to query optimization. When the target is 0, `ANALYZE` ignores the column. For example, the following `ALTER TABLE` command sets the statistics target for the `notes` column in the `emp` table to zero:

```
ALTER TABLE emp ALTER COLUMN notes SET STATISTICS 0;
```

The statistics target can be set in the range 0 to 1000, or set it to -1 to revert to using the system default statistics target.

Setting the statistics target on a parent partitioned table affects the child partitions. If you set statistics to 0 on some columns on the parent table, the statistics for the same columns are set to 0 for all children partitions. However, if you later add or exchange another child partition, the new child partition will use either the default statistics target or, in the case of an exchange, the previous statistics target. Therefore, if you add or exchange child partitions, you should set the statistics targets on the new child table.

Automatic Statistics Collection

WarehousePG can be set to automatically run `ANALYZE` on a table that either has no statistics or has changed significantly when certain operations are performed on the table. For partitioned tables, automatic statistics collection is only triggered when the operation is run directly on a leaf table, and then only the leaf table is analyzed.

Automatic statistics collection is governed by a server configuration parameter, and has three modes:

- `none` deactivates automatic statistics collection.
- `on_no_stats` triggers an analyze operation for a table with no existing statistics when any of the commands `CREATE TABLE AS SELECT`, `INSERT`, or `COPY` are run on the table by the table owner.
- `on_change` triggers an analyze operation when any of the commands `CREATE TABLE AS SELECT`, `UPDATE`, `DELETE`, `INSERT`, or `COPY` are run on the table by the table owner, and the number of rows affected exceeds the threshold defined by the `gp_autostats_on_change_threshold` configuration parameter.

The automatic statistics collection mode is set separately for commands that occur within a procedural language function and commands that run outside of a function:

- The `gp_autostats_mode` configuration parameter controls automatic statistics collection behavior outside of functions and is set to `on_no_stats` by default.

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- The `gp_autostats_mode_in_functions` parameter controls the behavior when table operations are performed within a procedural language function and is set to `none` by default.

With the `on_change` mode, `ANALYZE` is triggered only if the number of rows affected exceeds the threshold defined by the `gp_autostats_on_change_threshold` configuration parameter. The default value for this parameter is a very high value, 2147483647, which effectively deactivates automatic statistics collection; you must set the threshold to a lower number to enable it. The `on_change` mode could trigger large, unexpected analyze operations that could disrupt the system, so it is not recommended to set it globally. It could be useful in a session, for example to automatically analyze a table following a load.

Setting the `gp_autostats_allow_nonowner` server configuration parameter to `true` also instructs WarehousePG to trigger automatic statistics collection on a table when:

- `gp_autostats_mode=on_change` and the table is modified by a non-owner.
- `gp_autostats_mode=on_no_stats` and the first user to `INSERT` or `COPY` into the table is a non-owner.

To deactivate automatic statistics collection outside of functions, set the `gp_autostats_mode` parameter to `none`:

```
gpconfigure -c gp_autostats_mode -v none
```

To enable automatic statistics collection in functions for tables that have no statistics, change `gp_autostats_mode_in_functions` to `on_no_stats`:

```
gpconfigure -c gp_autostats_mode_in_functions -v on_no_stats
```

Set the `log_autostats` system configuration parameter to on if you want to log automatic statistics collection operations.

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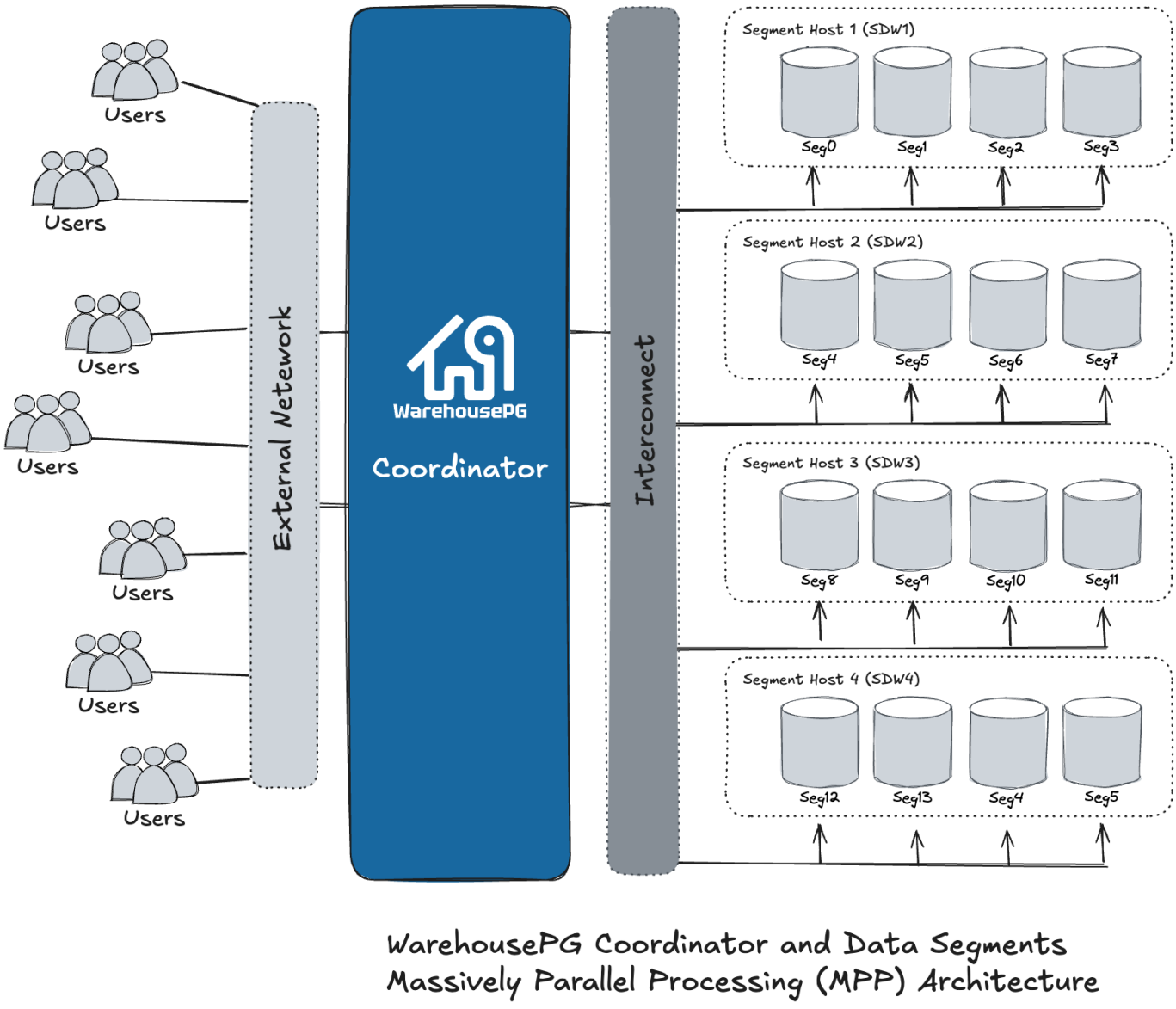
4.1.7 Introduction to WarehousePG

High-level overview of the WarehousePG cluster architecture.

WarehousePG stores and processes large amounts of data by distributing the load across several servers or *hosts*. A logical database in WarehousePG is an *array* of individual PostgreSQL databases working together to present a single database image. The *coordinator* is the entry point to the WarehousePG cluster. It is the database instance to which users connect and submit SQL statements. The coordinator coordinates the workload across the other database instances in the system, called *segments*, which handle data processing and storage. The segments communicate with each other and the coordinator over the *interconnect*, the networking layer of WarehousePG.

WarehousePG Architecture



WarehousePG is a software-only solution; the hardware and database software are not coupled. WarehousePG runs on a variety of commodity server platforms from WarehousePG-certified hardware vendors. Performance depends on the hardware on which it is installed. Because the database is distributed across multiple machines in a WarehousePG cluster, proper selection and configuration of hardware is vital to achieving the best possible performance.

This chapter describes the major components of a WarehousePG cluster and the hardware considerations and concepts associated with each component: The WarehousePG Coordinator, The Segments and The Interconnect. Additionally, a system may have optional ETL Hosts for Data Loading.

- The WarehousePG Coordinator
- The Segments
- The Interconnect
- ETL Hosts for Data Loading

Parent topic: Installing and Upgrading WarehousePG

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The WarehousePG Coordinator

The *coordinator* is the entry point to the WarehousePG cluster. It is the database server process that accepts client connections and processes the SQL commands that system users issue. Users connect to WarehousePG through the coordinator using a PostgreSQL-compatible client program such as `psql` or ODBC.

The coordinator maintains the *system catalog* (a set of system tables that contain metadata about the WarehousePG cluster itself), however the coordinator does not contain any user data. Data resides only on the *segments*. The coordinator authenticates client connections, processes incoming SQL commands, distributes the work load between segments, coordinates the results returned by each segment, and presents the final results to the client program.

Because the coordinator does not contain any user data, it has very little disk load. The coordinator needs a fast, dedicated CPU for data loading, connection handling, and query planning because extra space is often necessary for landing load files and backup files, especially in production environments. Customers may decide to also run ETL and reporting tools on the coordinator, which requires more disk space and processing power.

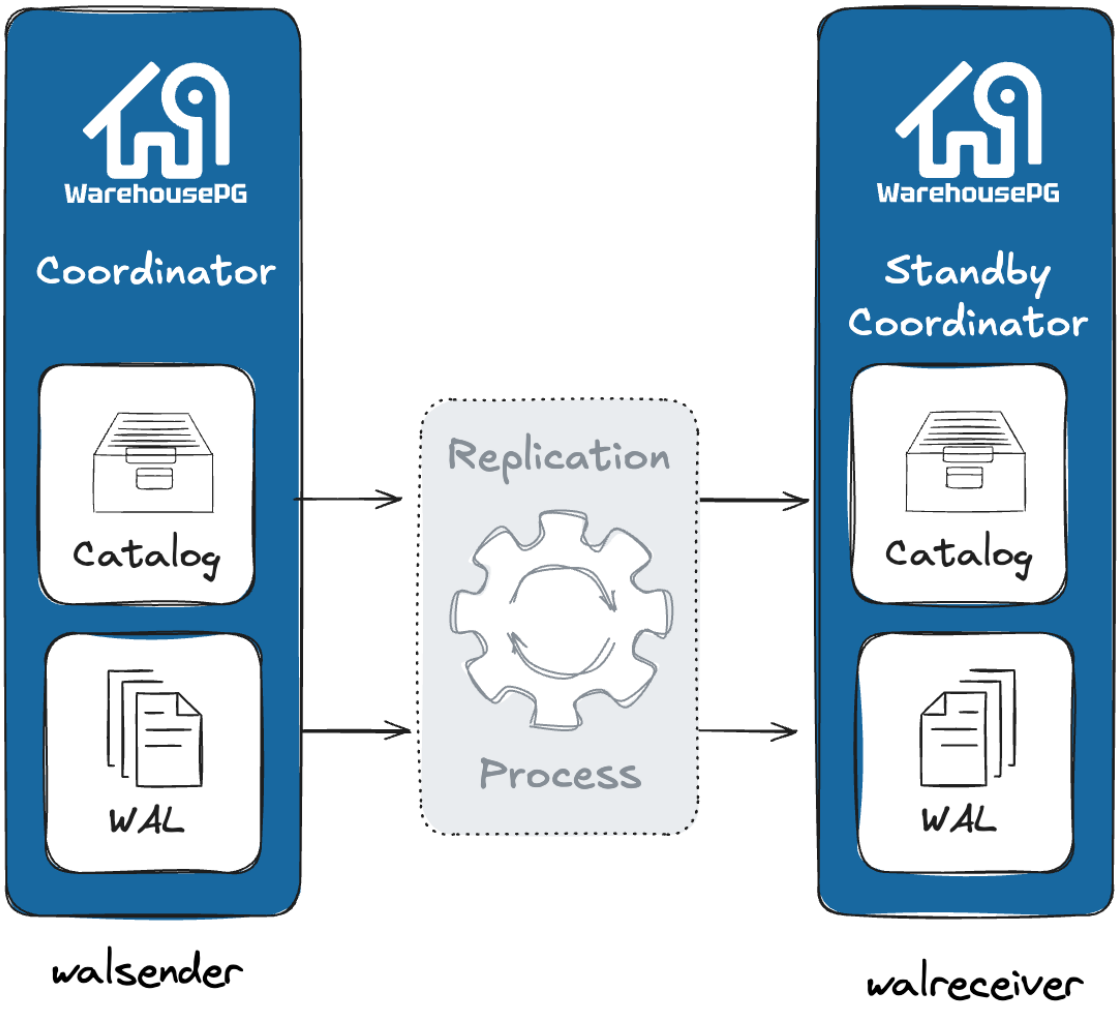
Parent topic: Introduction to WarehousePG

Coordinator Redundancy

You may optionally deploy a *backup* or *mirror* of the coordinator instance. A backup coordinator host serves as a *warm standby* if the primary coordinator host becomes nonoperational. You can deploy the standby coordinator on a designated redundant coordinator host or on one of the segment hosts.

The standby coordinator is kept up to date by a transaction log replication process, which runs on the standby coordinator host and synchronizes the data between the primary and standby coordinator hosts. If the primary coordinator fails, the log replication process shuts down, and an administrator can activate the standby coordinator in its place. When the standby coordinator is active, the replicated logs are used to reconstruct the state of the coordinator host at the time of the last successfully committed transaction.

Since the coordinator does not contain any user data, only the system catalog tables need to be synchronized between the primary and backup copies. When these tables are updated, changes automatically copy over to the standby coordinator so it is always synchronized with the primary.



The Segments

In WarehousePG, the *segments* are where data is stored and where most query processing occurs. User-defined tables and their indexes are distributed across the available segments in the WarehousePG cluster; each segment contains a distinct portion of the data. Segment instances are the database server processes that serve segments. Users do not interact directly with the segments in a WarehousePG cluster, but do so through the coordinator.

In the reference WarehousePG hardware configurations, the number of segment instances per segment host is determined by the number of effective CPUs or CPU core. For example, if your segment hosts have two dual-core processors, you may have two or four primary segments per host. If your segment hosts have three quad-core processors, you may have three, six or twelve segments per host. Performance testing will help decide the best number of segments for a chosen hardware platform.

Parent topic: Introduction to WarehousePG

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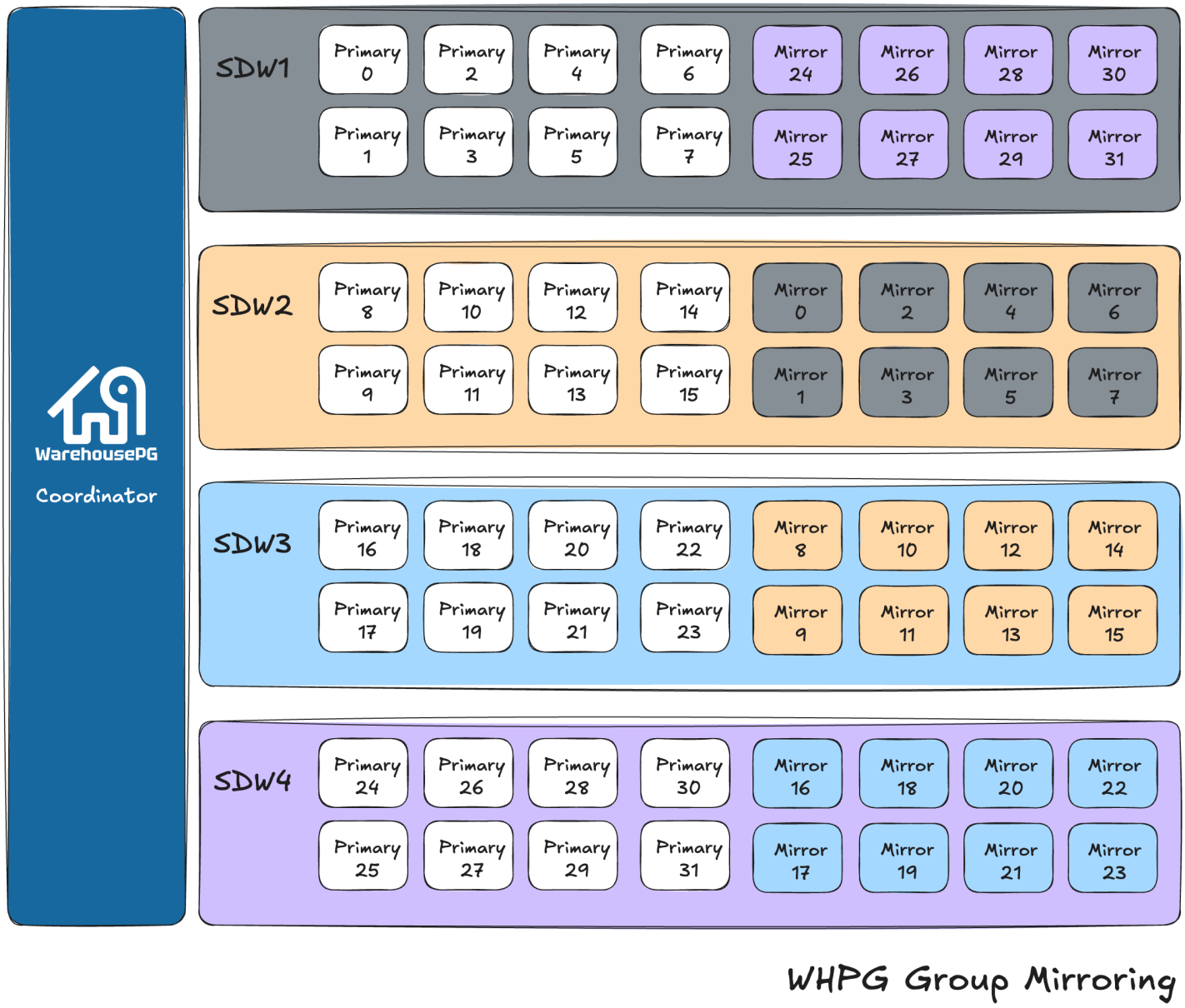
Segment Redundancy & Mirroring

When you deploy your WarehousePG cluster, you have the option to configure *mirror* segments. Mirror segments allow database queries to fail over to a backup segment if the primary segment becomes unavailable. Mirroring is a requirement for production WarehousePG clusters.

A mirror segment must always reside on a different host than its primary segment. Mirror segments can be arranged across the hosts in the system in one of two standard configurations, or in a custom configuration you design. The default configuration, called ***group*** mirroring, places the mirror segments for all primary segments on one other host. Another option, called ***spread*** mirroring, spreads mirrors for each host's primary segments over the remaining hosts. Spread mirroring requires that there be more hosts in the system than there are primary segments on the host. On hosts with multiple network interfaces, the primary and mirror segments are distributed equally among the interfaces. The following figure shows how table data is distributed across the segments when the default group mirroring option is configured.

Group Mirroring



Spread Mirroring

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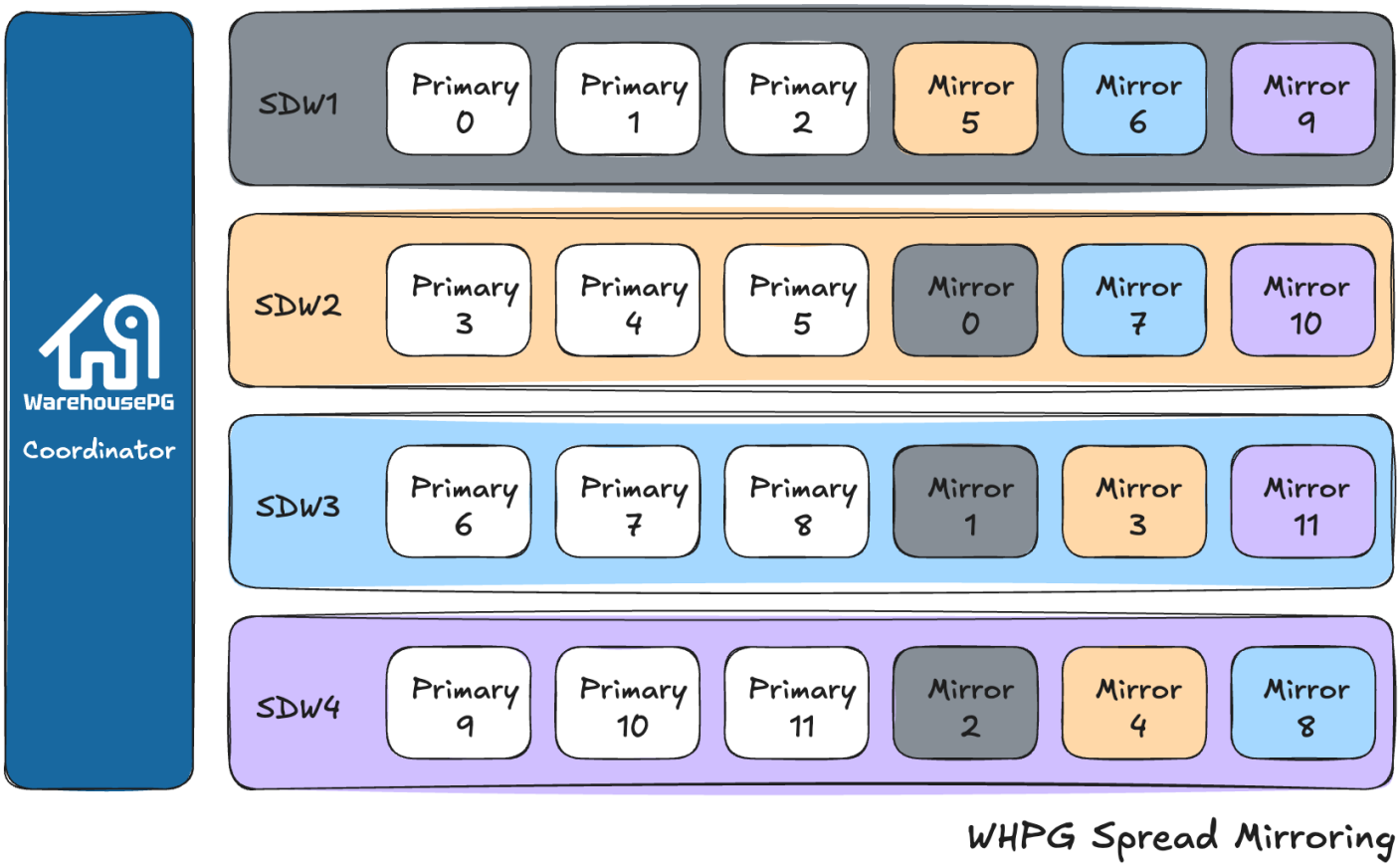

Block Mirroring

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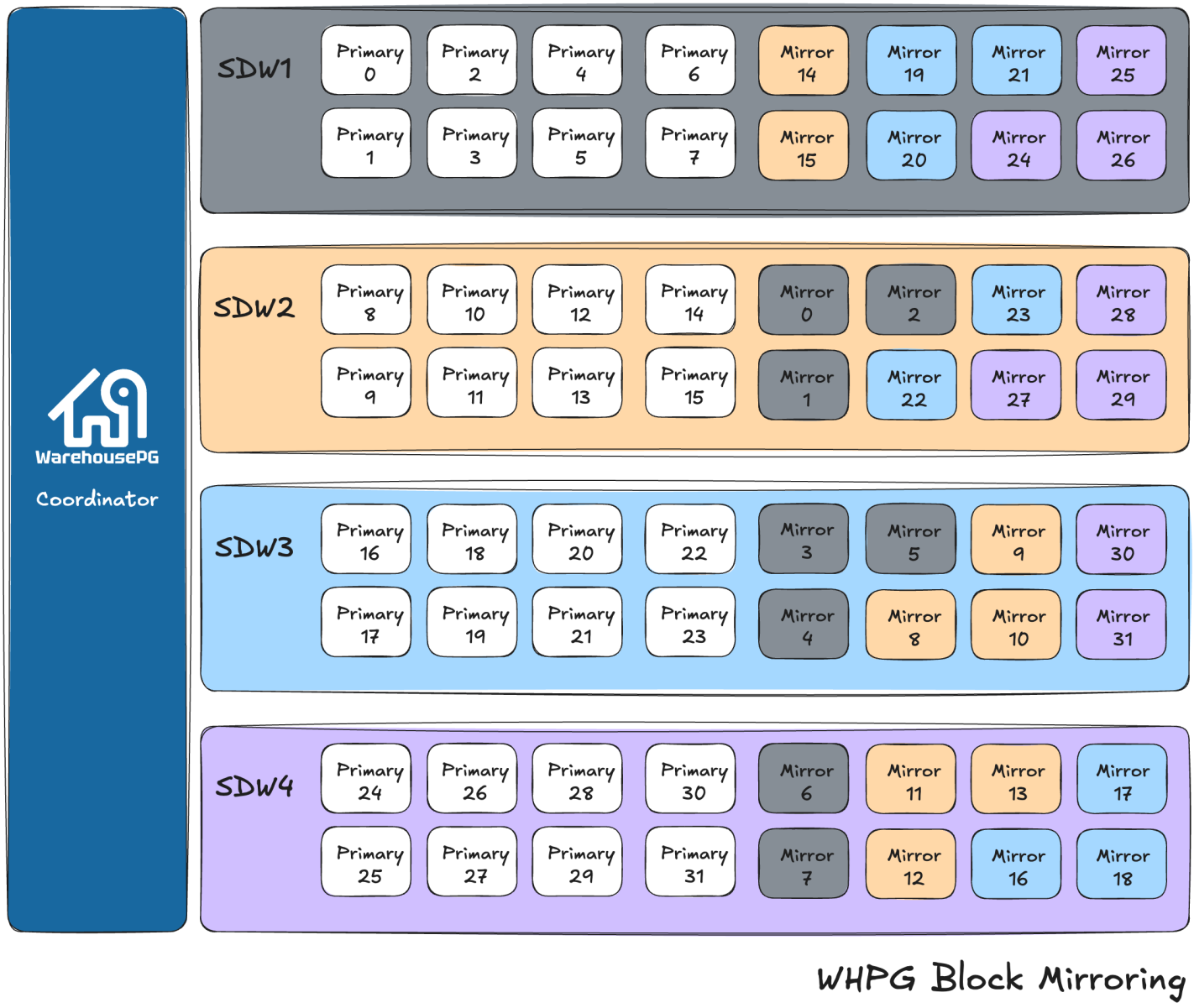

Segment Failover and Recovery

When mirroring is enabled in a WarehousePG cluster, the system automatically fails over to the mirror copy if a primary copy becomes unavailable. A WarehousePG cluster can remain operational if a segment instance or host goes down only if all portions of data are available on the remaining active segments.

If the coordinator cannot connect to a segment instance, it marks that segment instance as *invalid* in the WarehousePG cluster catalog. The segment instance remains invalid and out of operation until an administrator brings that segment back online. An administrator can recover a failed segment while the system is up and running. The recovery process copies over only the changes that were missed while the segment was nonoperational.

If you do not have mirroring enabled and a segment becomes invalid, the system automatically shuts down. An administrator must recover all failed segments before operations can continue.

Example Segment Host Hardware Stack

Regardless of the hardware platform you choose, a production WarehousePG processing node (a segment host) is typically configured as described in this section.

The segment hosts do the majority of database processing, so the segment host servers are configured in order to achieve the best performance possible from your WarehousePG cluster. WarehousePG's performance will be as fast as the slowest segment server in the array. Therefore, it is important to ensure that the underlying hardware and operating systems that are running WarehousePG are all running at their optimal performance level. It is also advised that all segment hosts in a WarehousePG cluster have identical hardware resources and configurations.

Segment hosts should also be dedicated to WarehousePG operations only. To get the best query performance, you do not want WarehousePG competing with other applications for machine or network resources.

The following diagram shows an example WarehousePG segment host hardware stack. The number of effective CPUs on a host is the basis for determining how many primary WarehousePG segment instances to deploy per segment host. This example shows a host with two effective CPUs (one dual-core CPU). Note that there is one primary segment instance (or primary/mirror pair if using mirroring) per CPU core.

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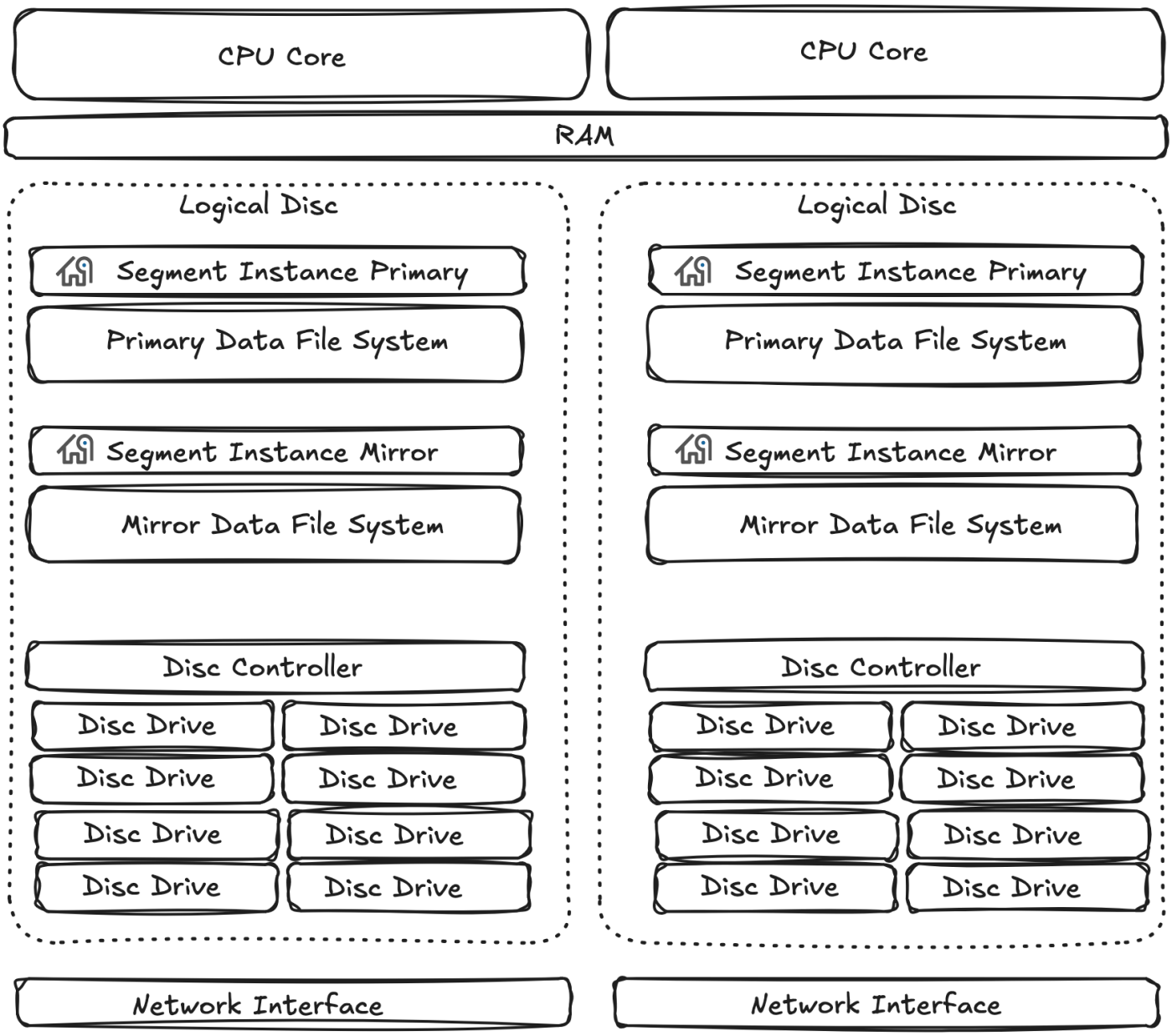

Example Segment Disk Layout

Each CPU is typically mapped to a logical disk. A logical disk consists of one primary file system (and optionally a mirror file system) accessing a pool of physical disks through an I/O channel or disk controller. The logical disk and file system are provided by the operating system. Most operating systems provide the ability for a logical disk drive to use groups of physical disks arranged in RAID arrays.

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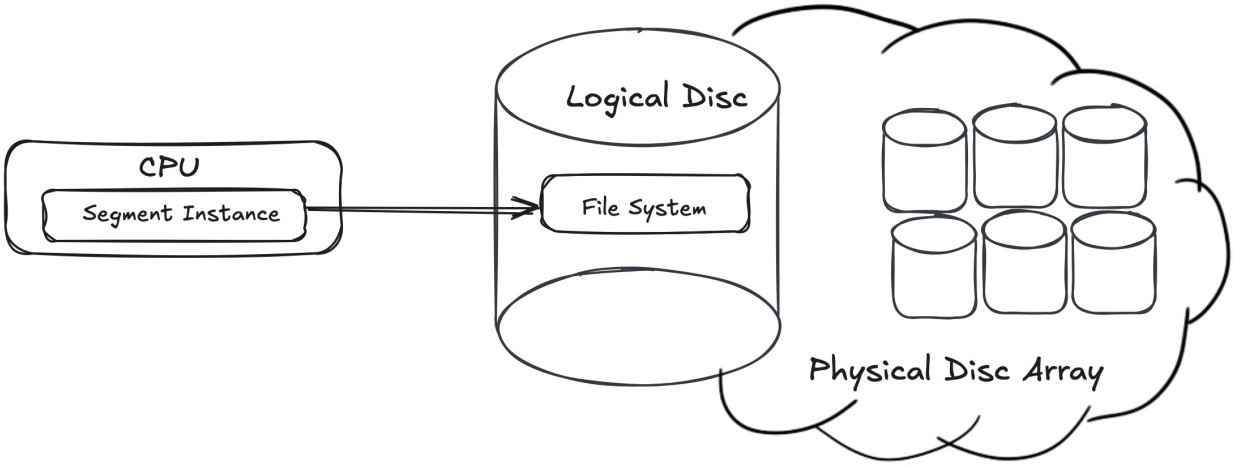

Depending on the hardware platform you choose, different RAID configurations offer different performance and capacity levels. WarehousePG supports and certifies a number of reference hardware platforms and operating systems. Check with your sales account representative for the recommended configuration on your chosen platform.

The Interconnect

The *interconnect* is the networking layer of WarehousePG. When a user connects to a database and issues a query, processes are created on each of the segments to handle the work of that query. The *interconnect* refers to the inter-process communication between the segments, as well as the network infrastructure on which this communication relies. The interconnect uses a standard 10 Gigabit Ethernet switching fabric.

By default, WarehousePG interconnect uses UDP (User Datagram Protocol) with flow control for interconnect traffic to send messages over the network. The WarehousePG software does the additional packet verification and checking not performed by UDP, so the reliability is equivalent to TCP (Transmission Control Protocol), and the performance and scalability exceeds that of TCP. For information about the types of interconnect supported by WarehousePG, see server configuration parameter `gp_interconnect_type` in the *WarehousePG Reference Guide*.

Parent topic: Introduction to WarehousePG

Interconnect Redundancy

A highly available interconnect can be achieved by deploying dual 10 Gigabit Ethernet switches on your network, and redundant 10 Gigabit connections to the WarehousePG coordinator and segment host servers.

Network Interface Configuration

A segment host typically has multiple network interfaces designated to WarehousePG interconnect traffic. The coordinator host typically has additional external network interfaces in addition to the interfaces used for interconnect traffic.

Depending on the number of interfaces available, you will want to distribute interconnect network traffic across the number of available interfaces. This is done by assigning segment instances to a particular network interface and ensuring that the primary segments are evenly balanced over the number of available interfaces.

This is done by creating separate host address names for each network interface. For example, if a host has four network interfaces, then it would have four corresponding host addresses, each of which maps to one or more primary segment instances. The `/etc/hosts` file should be configured to contain not only the host name of each machine, but also all interface host addresses for all of the WarehousePG hosts (coordinator, standby coordinator, segments, and ETL hosts).

With this configuration, the operating system automatically selects the best path to the destination. WarehousePG automatically balances the network destinations to maximize parallelism.

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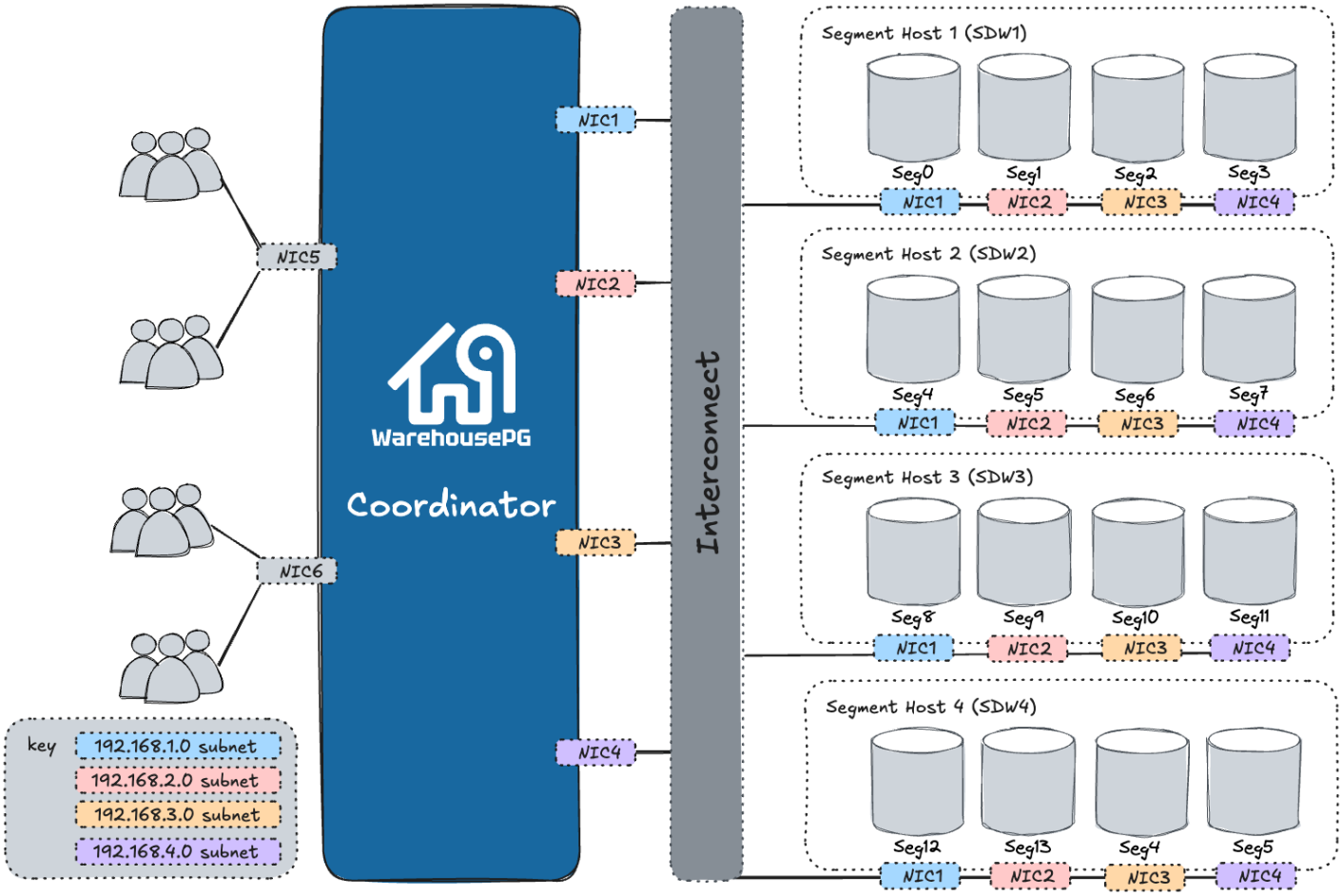

Switch Configuration

When using multiple 10 Gigabit Ethernet switches within your WarehousePG cluster, evenly divide the number of subnets between each switch. In this example configuration, if we had two switches, NICs 1 and 2 on each host would use switch 1 and NICs 3 and 4 on each host would use switch 2. For the coordinator host, the host name bound to NIC 1 (and therefore using switch 1) is the effective coordinator host name for the array. Therefore, if deploying a warm standby coordinator for redundancy purposes, the standby coordinator should map to a NIC that uses a different switch than the primary coordinator.

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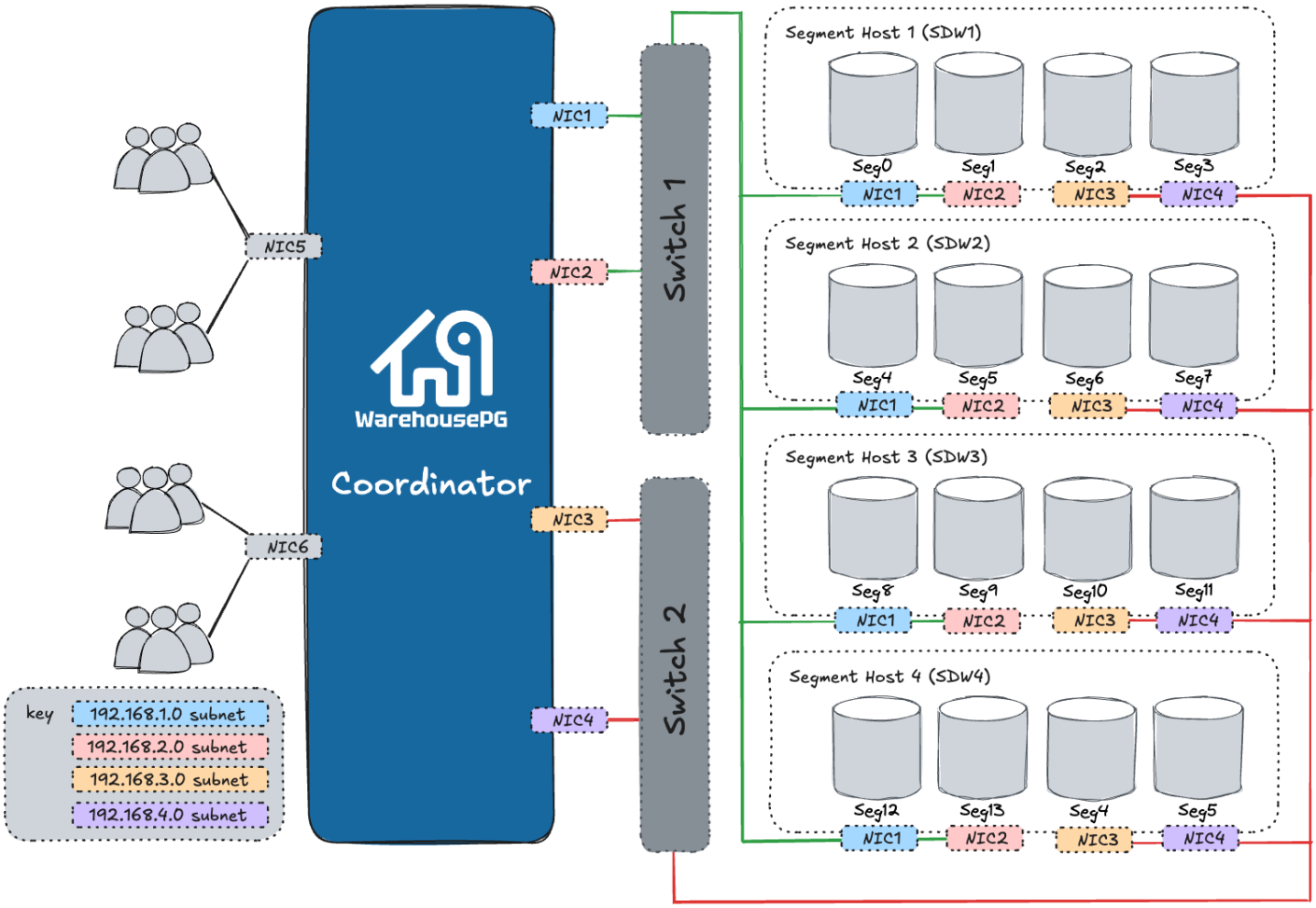

ETL Hosts for Data Loading

WarehousePG supports fast, parallel data loading with its external tables feature. By using external tables in conjunction with WarehousePG's parallel file server (`gpfdist`), administrators can achieve maximum parallelism and load bandwidth from their WarehousePG cluster. Many production systems deploy designated ETL servers for data loading purposes. These machines run the WarehousePG parallel file server (`gpfdist`), but not WarehousePG instances.

One advantage of using the `gpfdist` file server program is that it ensures that all of the segments in your WarehousePG cluster are fully utilized when reading from external table data files.

The `gpfdist` program can serve data to the segment instances at an average rate of about 350 MB/s for delimited text formatted files and 200 MB/s for CSV formatted files. Therefore, you should consider the following options when running `gpfdist` in order to maximize the network bandwidth of your ETL systems:

- If your ETL machine is configured with multiple network interface cards (NICs) as described in Network Interface Configuration, run one instance of `gpfdist` on your ETL host and then define your external table definition so that the host name of each NIC is declared in the `LOCATION` clause (see `CREATE EXTERNAL TABLE` in the *WarehousePG Reference Guide*). This allows network traffic between your WarehousePG segment hosts and your ETL host to use all NICs simultaneously.

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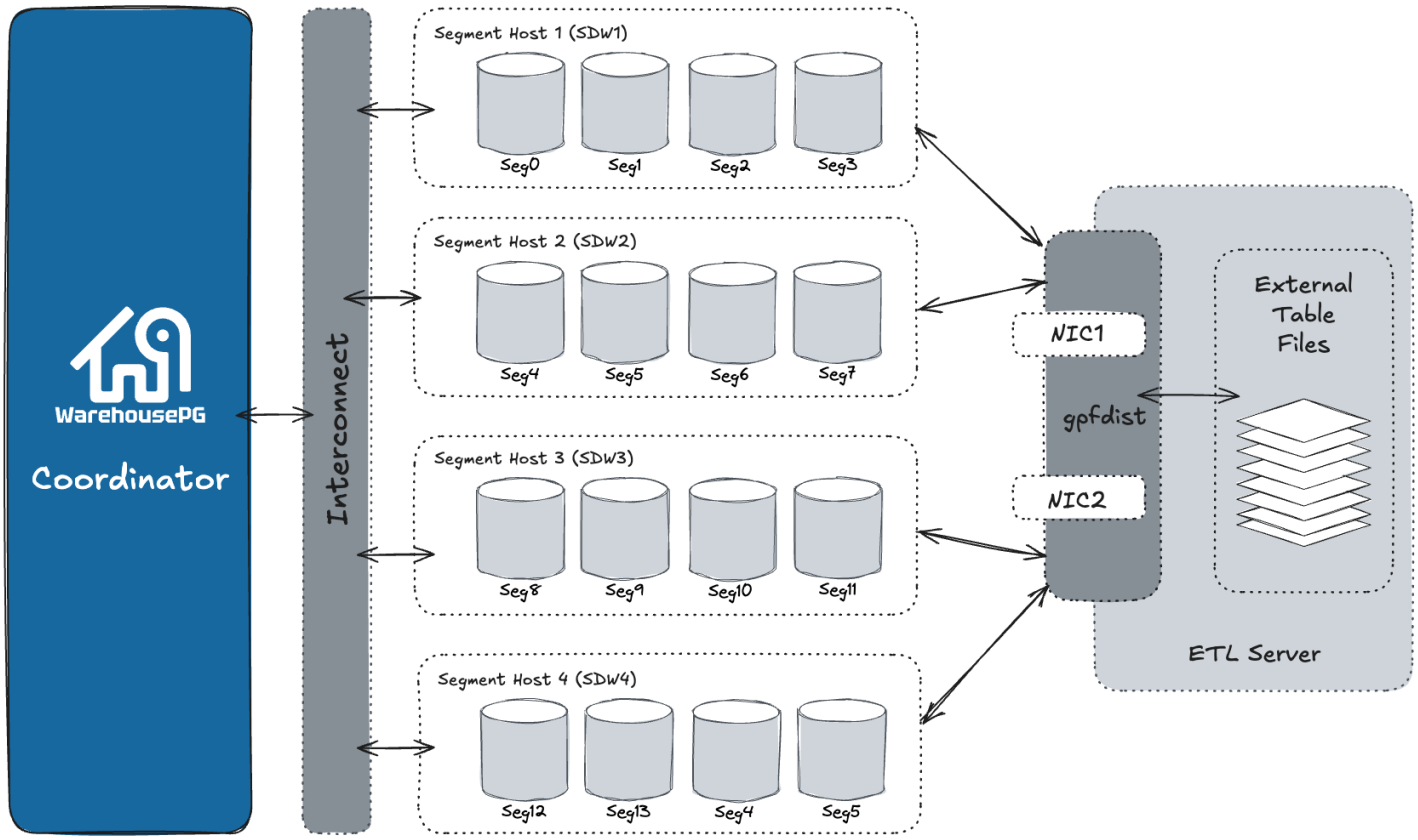
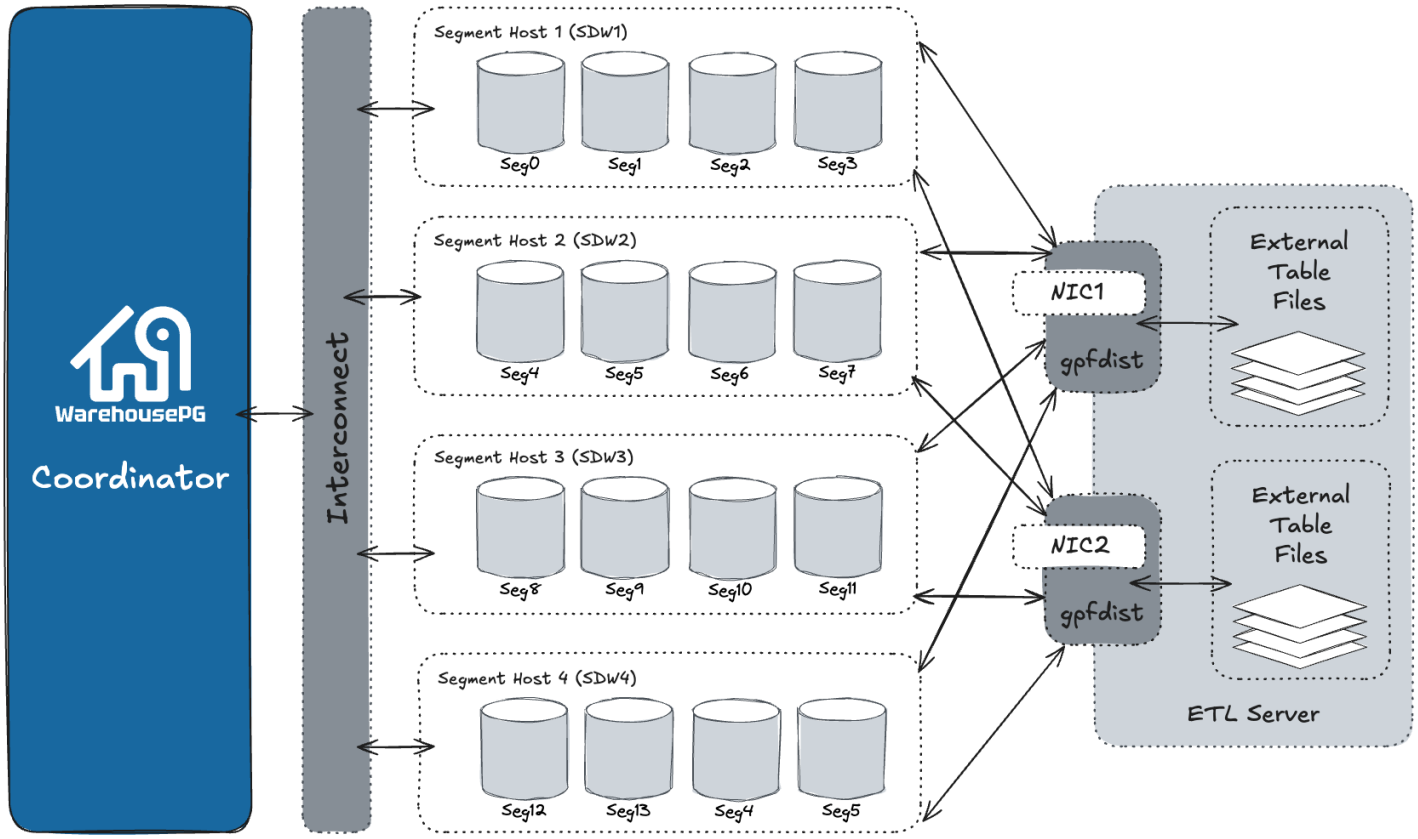


- Run multiple `gpfdist` instances on your ETL host and divide your external data files equally between each instance. For example, if you have an ETL system with two network interface cards (NICs), then you could run two `gpfdist` instances on that machine to maximize your load performance. You would then divide the external table data files evenly between the two `gpfdist` programs.



Parent topic: Introduction to WarehousePG

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4.2 Managing a WarehousePG Cluster

This section describes basic system administration tasks performed by a WarehousePG cluster administrator.

- About the WarehousePG Release Version Number
  WarehousePG version numbers and the way they change identify what has been modified from one WarehousePG release to the next.
- Starting and Stopping WarehousePG
  In a WarehousePG DBMS, the database server instances (the coordinator and all segments) are started or stopped across all of the hosts in the system in such a way that they can work together as a unified DBMS.
- Accessing the Database
  This topic describes the various client tools you can use to connect to WarehousePG, and how to establish a database session.
- Configuring the WarehousePG cluster
  Server configuration parameters affect the behavior of WarehousePG.
- Enabling Compression
  You can configure WarehousePG to use data compression with some database features and with some utilities.
- Configuring Proxies for the WarehousePG Interconnect
  You can configure a WarehousePG cluster to use proxies for interconnect communication to reduce the use of connections and ports during query processing.
- Enabling High Availability and Data Consistency Features
  The fault tolerance and the high-availability features of WarehousePG can be configured.
- Backing Up and Restoring Databases
  This topic describes how to use WarehousePG backup and restore features.
- Expanding a WarehousePG cluster
  To scale up performance and storage capacity, expand your WarehousePG cluster by adding hosts to the system. In general, adding nodes to a WarehousePG cluster achieves a linear scaling of performance and storage capacity.
- Monitoring a WarehousePG cluster
  You can monitor a WarehousePG cluster using a variety of tools included with the system or available as add-ons.
- Monitoring Long-Running Operations
  You can monitor, at run time, the progress of certain SQL and utility commands.
- Routine System Maintenance Tasks
  To keep a WarehousePG cluster running efficiently, the database must be regularly cleared of expired data and the table statistics must be updated so that the query optimizer has accurate information.
- Recommended Monitoring and Maintenance Tasks
  This section lists monitoring and maintenance activities recommended to ensure high availability and consistent performance of your WarehousePG cluster.

Parent topic: WarehousePG Administrator Guide

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4.2.1 About the WarehousePG Release Version Number

WarehousePG version numbers and the way they change identify what has been modified from one WarehousePG release to the next.

A WarehousePG release version number takes the format x.y.z, where:

- x identifies the Major version number
- y identifies the Minor version number
- z identifies the Patch version number

WarehousePG releases that have the same Major release number are guaranteed to be backwards compatible. WarehousePG increments the Major release number when the catalog changes or when incompatible feature changes or new features are introduced. Previously deprecated functionality may be removed in a major release.

The Minor release number for a given Major release increments when backwards compatible new features are introduced or when a WarehousePG feature is deprecated. (Previously deprecated functionality will never be removed in a minor release.)

WarehousePG increments the Patch release number for a given Minor release for backwards-compatible bug fixes.

Parent topic: Managing a WarehousePG cluster

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4.2.2 Starting and Stopping WarehousePG

In a WarehousePG DBMS, the database server instances (the coordinator and all segments) are started or stopped across all of the hosts in the system in such a way that they can work together as a unified DBMS.

Because a WarehousePG cluster is distributed across many machines, the process for starting and stopping a WarehousePG cluster is different than the process for starting and stopping a regular PostgreSQL DBMS.

Use the `gpstart` and `gpstop` utilities to start and stop WarehousePG, respectively. These utilities are located in the $GPHOME/bin directory on your WarehousePG coordinator host.

> **Important** Do not issue a `kill` command to end any Postgres process. Instead, use the database command `pg_cancel_backend()`.

Issuing a `kill -9` or `kill -11` can introduce database corruption and prevent root cause analysis from being performed.

For information about `gpstart` and `gpstop`, see the *WarehousePG Utility Guide*.

Parent topic: Managing a WarehousePG cluster

Starting WarehousePG

Start an initialized WarehousePG cluster by running the `gpstart` utility on the coordinator instance.

Use the `gpstart` utility to start a WarehousePG cluster that has already been initialized by the `gpinitsystem` utility, but has been stopped by the `gpstop` utility. The `gpstart` utility starts WarehousePG by starting all the Postgres database instances on the WarehousePG cluster. `gpstart` orchestrates this process and performs the process in parallel.

Run `gpstart` on the coordinator host to start WarehousePG:

```
$ gpstart
```

Restarting WarehousePG

Stop the WarehousePG cluster and then restart it.

The `gpstop` utility with the `-r` option can stop and then restart WarehousePG after the shutdown completes.

To restart WarehousePG, enter the following command on the coordinator host:

```
$ gpstop -r
```

Reloading Configuration File Changes Only

Reload changes to WarehousePG configuration files without interrupting the system.

The `gpstop` utility can reload changes to the pg_hba.conf configuration file and to *runtime* parameters in the coordinator postgresql.conf file without service interruption. Active sessions pick up changes when they reconnect to the database. Many server configuration parameters require a full system restart (`gpstop -r`) to activate. For information about server configuration parameters, see the *WarehousePG Reference Guide*.

Reload configuration file changes without shutting down the WarehousePG cluster using the `gpstop` utility:

```
$ gpstop -u
```

Starting the Coordinator in Maintenance Mode

Start only the coordinator to perform maintenance or administrative tasks without affecting data on the segments.

Maintenance mode should only be used with direction from WarehousePG Technical Support. For example, you could connect to a database only on the coordinator instance in maintenance mode and edit system catalog settings. For more information about system catalog tables, see the *WarehousePG Reference Guide*.

1. Run `gpstart` using the -m option:

   ```
   $ gpstart -m
   ```

2. Connect to the coordinator in maintenance mode to do catalog maintenance. For example:

   ```
   $ PGOPTIONS='-c gp_role=utility' psql postgres
   ```

3. After completing your administrative tasks, stop the coordinator in maintenance mode. Then, restart it in production mode.

   ```
   $ gpstop -m
   $ gpstart
   ```

   > **Caution** Incorrect use of maintenance mode connections can result in an inconsistent system state. Only Technical Support should perform this operation.

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Stopping WarehousePG

The `gpstop` utility stops or restarts your WarehousePG cluster and always runs on the coordinator host. When activated, `gpstop` stops all `postgres` processes in the system, including the coordinator and all segment instances. The `gpstop` utility uses a default of up to 64 parallel worker threads to bring down the Postgres instances that make up the WarehousePG cluster. The system waits for any active transactions to finish before shutting down. If after two minutes there are still active connections, `gpstop` will prompt you to either continue waiting in smart mode, stop in fast mode, or stop in immediate mode. To stop WarehousePG immediately, use fast mode.

> **Important** Immediate shut down mode is not recommended. This mode stops all database processes without allowing the database server to complete transaction processing or clean up any temporary or in-process work files.

- To stop WarehousePG:

  ```
  $ gpstop
  ```

- To stop WarehousePG in fast mode:

  ```
  $ gpstop -M fast
  ```

  By default, you are not allowed to shut down WarehousePG if there are any client connections to the database. Use the `-M fast` option to roll back all in progress transactions and terminate any connections before shutting down.

Stopping Client Processes

WarehousePG launches a new backend process for each client connection. A WarehousePG user with `SUPERUSER` privileges can cancel and terminate these client backend processes.

Canceling a backend process with the `pg_cancel_backend()` function ends a specific queued or active client query. Terminating a backend process with the `pg_terminate_backend()` function terminates a client connection to a database.

The `pg_cancel_backend()` function has two signatures:

- `pg_cancel_backend( pid int4 )`
- `pg_cancel_backend( pid int4, msg text )`

The `pg_terminate_backend()` function has two similar signatures:

- `pg_terminate_backend( pid int4 )`
- `pg_terminate_backend( pid int4, msg text )`

If you provide a `msg`, WarehousePG includes the text in the cancel message returned to the client. `msg` is limited to 128 bytes; WarehousePG truncates anything longer.

The `pg_cancel_backend()` and `pg_terminate_backend()` functions return `true` if successful, and `false` otherwise.

To cancel or terminate a backend process, you must first identify the process ID of the backend. You can obtain the process ID from the `pid` column of the `pg_stat_activity` view. For example, to view the process information associated with all running and queued queries:

```
=# SELECT usename, pid, waiting, state, query, datname
     FROM pg_stat_activity;
```

Sample partial query output:

```
 usename |  pid     | waiting | state  |         query          | datname
---------+----------+---------+--------+------------------------+---------
  sammy  |   31861  |    f    | idle   | SELECT * FROM testtbl; | testdb
  billy  |   31905  |    t    | active | SELECT * FROM topten;  | testdb
```

Use the output to identify the process id (`pid`) of the query or client connection.

For example, to cancel the waiting query identified in the sample output above and include `'Admin canceled long-running query.'` as the message returned to the client:

```
=# SELECT pg_cancel_backend(31905 ,'Admin canceled long-running query.');
ERROR:  canceling statement due to user request: "Admin canceled long-running query."
```

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4.2.3 Accessing the Database

This topic describes the various client tools you can use to connect to WarehousePG, and how to establish a database session.

- Establishing a Database Session
- Supported Client Applications
- WarehousePG Client Applications
- Connecting with psql
- Using the PgBouncer Connection Pooler
- Database Application Interfaces
- Troubleshooting Connection Problems

Parent topic: Managing a WarehousePG cluster

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4.2.3.1 Establishing a Database Session

Users can connect to WarehousePG using a PostgreSQL-compatible client program, such as `psql`. Users and administrators *always* connect to WarehousePG through the *coordinator*; the segments cannot accept client connections.

In order to establish a connection to the WarehousePG coordinator, you will need to know the following connection information and configure your client program accordingly.

Connection Parameter	Description	Environment Variable
Application name	The application name that is connecting to the database. The default value, held in the `application_name` connection parameter is *psql*.	`$PGAPPNAME`
Database name	The name of the database to which you want to connect. For a newly initialized system, use the `postgres` database to connect for the first time.	`$PGDATABASE`
Host name	The host name of the WarehousePG coordinator. The default host is the local host.	`$PGHOST`
Port	The port number that the WarehousePG coordinator instance is running on. The default is 5432.	`$PGPORT`
User name	The database user (role) name to connect as. This is not necessarily the same as your OS user name. Check with your WarehousePG administrator if you are not sure what you database user name is. Note that every WarehousePG cluster has one superuser account that is created automatically at initialization time. This account has the same name as the OS name of the user who initialized the WarehousePG cluster (typically `gpadmin`).	`$PGUSER`

Connecting with psql provides example commands for connecting to WarehousePG.

Parent topic: Accessing the Database

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4.2.3.2 Supported Client Applications

Users can connect to WarehousePG using various client applications:

- A number of WarehousePG Client Applications are provided with your WarehousePG installation. The `psql` client application provides an interactive command-line interface to WarehousePG.
- Using standard Database Application Interfaces, such as ODBC and JDBC, users can create their own client applications that interface to WarehousePG.
- Most client tools that use standard database interfaces, such as ODBC and JDBC, can be configured to connect to WarehousePG.

> **Note**
>
> While WarehousePG is compatible with community PostgreSQL drivers, EDB recommends using the EDB ODBC Connector or the EDB JDBC Connector for production environments. These drivers are specifically optimized for EDB-supported Postgres distributions, including WarehousePG, and ensure full compatibility with enterprise security and performance features.
>
> Download these drivers from the EDB Connectors page.

Parent topic: Accessing the Database

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4.2.3.3 WarehousePG Client Applications

WarehousePG comes installed with a number of client utility applications located in the `$GPHOME/bin` directory of your WarehousePG coordinator host installation. The following are the most commonly used client utility applications:

Name	Usage
`createdb`	create a new database
`createuser`	define a new database role
`dropdb`	remove a database
`dropuser`	remove a role
`psql`	PostgreSQL interactive terminal
`reindexdb`	reindex a database
`vacuumdb`	garbage-collect and analyze a database

When using these client applications, you must connect to a database through the WarehousePG coordinator instance. You will need to know the name of your target database, the host name and port number of the coordinator, and what database user name to connect as. This information can be provided on the command-line using the options `-d`, `-h`, `-p`, and `-U` respectively. If an argument is found that does not belong to any option, it will be interpreted as the database name first.

All of these options have default values which will be used if the option is not specified. The default host is the local host. The default port number is 5432. The default user name is your OS system user name, as is the default database name. Note that OS user names and WarehousePG user names are not necessarily the same.

If the default values are not correct, you can set the environment variables `PGDATABASE`, `PGHOST`, `PGPORT`, and `PGUSER` to the appropriate values, or use a `psql` `~/.pgpass` file to contain frequently-used passwords.

For information about WarehousePG environment variables, see the *WarehousePG Reference Guide*. For information about psql, see the *WarehousePG Utility Guide*.

Parent topic: Accessing the Database

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4.2.3.4 Connecting with psql

Depending on the default values used or the environment variables you have set, the following examples show how to access a database via `psql`:

```
$ psql -d gpdatabase -h coordinator_host -p 5432 -U `gpadmin`
```

```
$ psql gpdatabase
```

```
$ psql
```

If a user-defined database has not yet been created, you can access the system by connecting to the `postgres` database. For example:

```
$ psql postgres
```

After connecting to a database, `psql` provides a prompt with the name of the database to which `psql` is currently connected, followed by the string `=>` (or `=#` if you are the database superuser). For example:

```
gpdatabase=>
```

At the prompt, you may type in SQL commands. A SQL command must end with a `;` (semicolon) in order to be sent to the server and run. For example:

```
=> SELECT * FROM mytable;
```

See the *WarehousePG Reference Guide* for information about using the `psql` client application and SQL commands and syntax.

Parent topic: Accessing the Database

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4.2.3.5 Using the PgBouncer Connection Pooler

The PgBouncer utility manages connection pools for PostgreSQL and WarehousePG connections.

The following topics describe how to set up and use PgBouncer with WarehousePG. Refer to the PgBouncer web site for information about using PgBouncer with PostgreSQL.

- Overview
- Migrating PgBouncer
- Configuring PgBouncer
- Starting PgBouncer
- Managing PgBouncer

Parent topic: Accessing the Database

Overview

A database connection pool is a cache of database connections. Once a pool of connections is established, connection pooling eliminates the overhead of creating new database connections, so clients connect much faster and the server load is reduced.

The PgBouncer connection pooler, from the PostgreSQL community, is included in your WarehousePG installation. PgBouncer is a light-weight connection pool manager for WarehousePG and PostgreSQL. PgBouncer maintains a pool for connections for each database and user combination. PgBouncer either creates a new database connection for a client or reuses an existing connection for the same user and database. When the client disconnects, PgBouncer returns the connection to the pool for re-use.

In order not to compromise transaction semantics for connection pooling, PgBouncer supports several types of pooling when rotating connections:

- *Session pooling* - Most polite method. When a client connects, a server connection will be assigned to it for the whole duration the client stays connected. When the client disconnects, the server connection will be put back into the pool. This is the default method.
- *Transaction pooling* - A server connection is assigned to a client only during a transaction. When PgBouncer notices that transaction is over, the server connection will be put back into the pool.
- *Statement pooling* - Most aggressive method. The server connection will be put back into the pool immediately after a query completes. Multi-statement transactions are disallowed in this mode as they would break.

You can set a default pool mode for the PgBouncer instance. You can override this mode for individual databases and users.

PgBouncer supports the standard connection interface shared by PostgreSQL and WarehousePG. The WarehousePG client application (for example, `psql`) connects to the host and port on which PgBouncer is running rather than the WarehousePG coordinator host and port.

PgBouncer includes a `psql`-like administration console. Authorized users can connect to a virtual database to monitor and manage PgBouncer. You can manage a PgBouncer daemon process via the admin console. You can also use the console to update and reload PgBouncer configuration at runtime without stopping and restarting the process.

PgBouncer natively supports TLS.

Migrating PgBouncer

When you migrate to a new WarehousePG version, you must migrate your PgBouncer instance to that in the new WarehousePG installation.

- **If you are migrating to a WarehousePG version 5.8.x or earlier**, you can migrate PgBouncer without dropping connections. Launch the new PgBouncer process with the `-R` option and the configuration file that you started the process with:

  ```
  $ pgbouncer -R -d pgbouncer.ini
  ```

  The `-R` (reboot) option causes the new process to connect to the console of the old process through a Unix socket and issue the following commands:

  ```
  SUSPEND;
  SHOW FDS;
  SHUTDOWN;
  ```

  When the new process detects that the old process is gone, it resumes the work with the old connections. This is possible because the `SHOW FDS` command sends actual file descriptors to the new process. If the transition fails for any reason, kill the new process and the old process will resume.

- **If you are migrating to a WarehousePG version 5.9.0 or later**, you must shut down the PgBouncer instance in your old installation and reconfigure and restart PgBouncer in your new installation.
- If you used stunnel to secure PgBouncer connections in your old installation, you must configure SSL/TLS in your new installation using the built-in TLS capabilities of PgBouncer 1.8.1 and later.
- If you currently use the built-in PAM LDAP integration, you may choose to migrate to the new native LDAP PgBouncer integration introduced in WarehousePG version 6.22; refer toConfiguring LDAP-based Authentication for PgBouncer for configuration information.

Configuring PgBouncer

You configure PgBouncer and its access to WarehousePG via a configuration file. This configuration file, commonly named `pgbouncer.ini`, provides location information for WarehousePGs. The `pgbouncer.ini` file also specifies process, connection pool, authorized users, and authentication configuration for PgBouncer.

Sample `pgbouncer.ini` file contents:

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```
[databases]
postgres = host=127.0.0.1 port=5432 dbname=postgres
pgb_mydb = host=127.0.0.1 port=5432 dbname=mydb

[pgbouncer]
pool_mode = session
listen_port = 6543
listen_addr = 127.0.0.1
auth_type = md5
auth_file = users.txt
logfile = pgbouncer.log
pidfile = pgbouncer.pid
admin_users = gpadmin
```

Refer to the pgbouncer.ini reference page for the PgBouncer configuration file format and the list of configuration properties it supports.

When a client connects to PgBouncer, the connection pooler looks up the the configuration for the requested database (which may be an alias for the actual database) that was specified in the `pgbouncer.ini` configuration file to find the host name, port, and database name for the database connection. The configuration file also identifies the authentication mode in effect for the database.

PgBouncer requires an authentication file, a text file that contains a list of WarehousePG users and passwords. The contents of the file are dependent on the `auth_type` you configure in the `pgbouncer.ini` file. Passwords may be either clear text or MD5-encoded strings. You can also configure PgBouncer to query the destination database to obtain password information for users that are not in the authentication file.

PgBouncer Authentication File Format

PgBouncer requires its own user authentication file. You specify the name of this file in the `auth_file` property of the `pgbouncer.ini` configuration file. `auth_file` is a text file in the following format:

```
"username1" "password" ...
"username2" "md5abcdef012342345" ...
"username2" "SCRAM-SHA-256$<iterations>:<salt>$<storedkey>:<serverkey>"
```

`auth_file` contains one line per user. Each line must have at least two fields, both of which are enclosed in double quotes (`" "`). The first field identifies the WarehousePG user name. The second field is either a plain-text password, an MD5-encoded password, or or a SCRAM secret. PgBouncer ignores the remainder of the line.

(The format of `auth_file` is similar to that of the `pg_auth` text file that WarehousePG uses for authentication information. PgBouncer can work directly with this WarehousePG authentication file.)

Use an MD5 encoded password. The format of an MD5 encoded password is:

```
"md5" + MD5_encoded(<password><username>)
```

You can also obtain the MD5-encoded passwords of all WarehousePG users from the `pg_shadow` view.

PostgreSQL SCRAM secret format:

```
SCRAM-SHA-256$<iterations>:<salt>$<storedkey>:<serverkey>
```

See the PostgreSQL documentation and RFC 5803 for details on this.

The passwords or secrets stored in the authentication file serve two purposes. First, they are used to verify the passwords of incoming client connections, if a password-based authentication method is configured. Second, they are used as the passwords for outgoing connections to the backend server, if the backend server requires password-based authentication (unless the password is specified directly in the database's connection string). The latter works if the password is stored in plain text or MD5-hashed.

SCRAM secrets can only be used for logging into a server if the client authentication also uses SCRAM, the PgBouncer database definition does not specify a user name, and the SCRAM secrets are identical in PgBouncer and the PostgreSQL server (same salt and iterations, not merely the same password). This is due to an inherent security property of SCRAM: The stored SCRAM secret cannot by itself be used for deriving login credentials.

The authentication file can be written by hand, but it's also useful to generate it from some other list of users and passwords. See `./etc/mkauth.py` for a sample script to generate the authentication file from the `pg_shadow` system table. Alternatively, use

```
auth_query
```

instead of `auth_file` to avoid having to maintain a separate authentication file.

Configuring HBA-based Authentication for PgBouncer

PgBouncer supports HBA-based authentication. To configure HBA-based authentication for PgBouncer, you set `auth_type=hba` in the `pgbouncer.ini` configuration file. You also provide the filename of the HBA-format file in the `auth_hba_file` parameter of the `pgbouncer.ini` file.

Contents of an example PgBouncer HBA file named `hba_bouncer.conf`:

```
local       all     bouncer             trust
host        all     bouncer      127.0.0.1/32       trust
```

Example excerpt from the related `pgbouncer.ini` configuration file:

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```
[databases]
p0 = port=15432 host=127.0.0.1 dbname=p0 user=bouncer pool_size=2
p1 = port=15432 host=127.0.0.1 dbname=p1 user=bouncer
...

[pgbouncer]
...
auth_type = hba
auth_file = userlist.txt
auth_hba_file = hba_bouncer.conf
...
```

Refer to the HBA file format discussion in the PgBouncer documentation for information about PgBouncer support of the HBA authentication file format.

Configuring LDAP-based Authentication for PgBouncer

Starting in WarehousePG version 6.22, PgBouncer supports native LDAP authentication between the `psql` client and the `pgbouncer` process. Configuring this LDAP-based authentication is similar to configuring HBA-based authentication for PgBouncer:

- Specify `auth-type=hba` in the `pgbouncer.ini` configuration file.
- Provide the file name of an HBA-format file in the `auth_hba_file` parameter of the `pgbouncer.ini` file, and specify the LDAP parameters (server address, base DN, bind DN, bind password, search attribute, etc.) in the file.

> **Note** You may, but are not required to, specify LDAP user names and passwords in the `auth-file`. When you do *not* specify these strings in the `auth-file`, LDAP user password changes require no PgBouncer configuration changes.

If you enable LDAP authentication between `psql` and `pgbouncer` and you use `md5`, `password`, or `scram-sha-256` for authentication between PgBouncer and WarehousePG, ensure that you configure the latter password independently.

Excerpt of an example PgBouncer HBA file named `hba_bouncer_for_ldap.conf` that specifies LDAP authentication follows:

```
host all user1 0.0.0.0/0 ldap ldapserver=<ldap-server-address> ldapbasedn="CN=Users,DC=greenplum,DC=org"
ldapbinddn="CN=Administrator,CN=Users,DC=greenplum,DC=org" ldapbindpasswd="ChangeMe1!!" ldapsearchattribute="SomeAttrName"
```

Refer to the WarehousePG LDAP Authentication discussion for more information on configuring an HBA file for LDAP.

Example excerpt from the related `pgbouncer.ini` configuration file:

```
[databases]
* = port = 6000 host=127.0.0.1

[pgbouncer]
listen_addr = 0.0.0.0
listen_port = 6432

auth_type = hba
auth_hba_file = hba_bouncer_for_ldap.conf
...
```

About Specifying an Encrypted LDAP Password

Starting in WarehousePG version 7.1, PgBouncer supports encrypted LDAP passwords. To utilize an encrypted LDAP password with PgBouncer, you must:

- Place the encrypted password in the `${HOME}/.ldapbindpass` file.
- Specify `ldapbindpasswd="$bindpasswd"` in the HBA-based authentication file for PgBouncer.
- Specify the file system path to the encryption key in the `auth_key_file` setting in the `pgbouncer.ini` configuration file.
- Specify the encryption cipher in the `auth_cipher` setting in the `pgbouncer.ini` configuration file.

The following example commands create an encrypted password and place it in `${HOME}/.ldapbindpass`:

```
# generate a key file named ldkeyfile
$ openssl rand -base64 256 | tr -d '\n' > ldkeyfile
# encrypt the password
$ encrypted_passwd=$(echo -n "your_secret_password_here" | openssl enc -aes-256-cbc -base64 -md sha256 -pass file:ldkeyfile
# copy the encrypted password to required location
$ echo -n $encrypted_passwd > "${HOME}/.ldapbindpass"
```

An excerpt of an example PgBouncer HBA file named `hba_bouncer_with_ldap_encrypted.conf` that specifies LDAP authentication with an encrypted password follows:

```
host all user2 0.0.0.0/0 ldap ldapserver=<ldap-server-address> ldapbindpasswd="$bindpasswd" ldapbasedn="CN=Users,DC=greenplum,DC=org"
ldapbinddn="CN=Administrator,CN=Users,DC=greenplum,DC=org" ldapsearchattribute="SomeAttrName"
```

Example excerpt from the related `pgbouncer.ini` configuration file:

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```
[databases]
* = port = 6000 host=127.0.0.1
[pgbouncer]
listen_addr = 0.0.0.0
listen_port = 6432
auth_type = hba
auth_hba_file = hba_bouncer_with_ldap_encrypted.conf
auth_key_file = /home/user2/ldkeyfile
auth_cipher = -aes-128-ecb
...
```

Starting PgBouncer

You can run PgBouncer on the WarehousePG coordinator or on another server. If you install PgBouncer on a separate server, you can easily switch clients to the standby coordinator by updating the PgBouncer configuration file and reloading the configuration using the PgBouncer Administration Console.

Follow these steps to set up PgBouncer.

1. Create a PgBouncer configuration file. For example, add the following text to a file named `pgbouncer.ini`:

   ```
   [databases]
   postgres = host=127.0.0.1 port=5432 dbname=postgres
   pgb_mydb = host=127.0.0.1 port=5432 dbname=mydb

   [pgbouncer]
   pool_mode = session
   listen_port = 6543
   listen_addr = 127.0.0.1
   auth_type = md5
   auth_file = users.txt
   logfile = pgbouncer.log
   pidfile = pgbouncer.pid
   admin_users = gpadmin
   ```

   The file lists databases and their connection details. The file also configures the PgBouncer instance. Refer to the pgbouncer.ini reference page for information about the format and content of a PgBouncer configuration file.

2. Create an authentication file. The filename should be the name you specified for the `auth_file` parameter of the `pgbouncer.ini` file, `users.txt`. Each line contains a user name and password. The format of the password string matches the `auth_type` you configured in the PgBouncer configuration file. If the `auth_type` parameter is `plain`, the password string is a clear text password, for example:

   ```
   "gpadmin" "gpadmin1234"
   ```

   If the `auth_type` in the following example is `md5`, the authentication field must be MD5-encoded. The format for an MD5-encoded password is:

   ```
   "md5" + MD5_encoded(<password><username>)
   ```

3. Launch `pgbouncer`:

   ```
   $ $GPHOME/bin/pgbouncer -d pgbouncer.ini
   ```

   The `-d` option runs PgBouncer as a background (daemon) process. Refer to the pgbouncer reference page for the `pgbouncer` command syntax and options.

4. Update your client applications to connect to `pgbouncer` instead of directly to WarehousePG server. For example, to connect to the WarehousePG named `mydb` configured above, run `psql` as follows:

   ```
   $ psql -p 6543 -U someuser pgb_mydb
   ```

   The `-p` option value is the `listen_port` that you configured for the PgBouncer instance.

Managing PgBouncer

PgBouncer provides a `psql`-like administration console. You log in to the PgBouncer Administration Console by specifying the PgBouncer port number and a virtual database named `pgbouncer`. The console accepts SQL-like commands that you can use to monitor, reconfigure, and manage PgBouncer.

For complete documentation of PgBouncer Administration Console commands, refer to the pgbouncer-admin command reference.

Follow these steps to get started with the PgBouncer Administration Console.

1. Use `psql` to log in to the `pgbouncer` virtual database:

   ```
   $ psql -p 6543 -U username pgbouncer
   ```

   The username that you specify must be listed in the `admin_users` parameter in the `pgbouncer.ini` configuration file. You can also log in to the PgBouncer Administration Console with the current Unix username if the `pgbouncer` process is running under that user's UID.

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2. To view the available PgBouncer Administration Console commands, run the `SHOW help` command:

```
pgbouncer=# SHOW help;
NOTICE:  Console usage
DETAIL:
    SHOW HELP|CONFIG|DATABASES|FDS|POOLS|CLIENTS|SERVERS|SOCKETS|LISTS|VERSION|...
    SET key = arg
    RELOAD
    PAUSE
    SUSPEND
    RESUME
    SHUTDOWN
    [...]
```

3. If you update PgBouncer configuration by editing the `pgbouncer.ini` configuration file, you use the `RELOAD` command to reload the file:

```
pgbouncer=# RELOAD;
```

Mapping PgBouncer Clients to WarehousePG Server Connections

To map a PgBouncer client to a WarehousePG server connection, use the PgBouncer Administration Console `SHOW CLIENTS` and `SHOW SERVERS` commands:

1. Use `ptr` and `link` to map the local client connection to the server connection.
2. Use the `addr` and the `port` of the client connection to identify the TCP connection from the client.
3. Use `local_addr` and `local_port` to identify the TCP connection to the server.

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4.2.3.6 Database Application Interfaces

You may want to develop your own client applications that interface to WarehousePG. PostgreSQL provides a number of database drivers for the most commonly used database application programming interfaces (APIs), which can also be used with WarehousePG. These drivers are available as a separate download. Each driver (except libpq, which comes with PostgreSQL) is an independent PostgreSQL development project and must be downloaded, installed and configured to connect to WarehousePG. The following drivers are available:

API	PostgreSQL Driver	Download Link
ODBC	EDB ODBC Connector	EDB Connectors page
JDBC	EDB JDBC Connector	EDB Connectors page
Perl DBI	pgperl	https://metacpan.org/release/DBD-Pg
Python DBI	pygresql	http://www.pygresql.org/
Python DBI	psycopg2	https://www.psycopg.org/
libpq C Library	libpq	https://www.postgresql.org/docs/12/libpq.html

> **Note**
>
> While WarehousePG is compatible with community PostgreSQL drivers, EDB recommends using the EDB ODBC Connector or the EDB JDBC Connector for production environments. These drivers are specifically optimized for EDB-supported Postgres distributions, including WarehousePG, and ensure full compatibility with enterprise security and performance features.

General instructions for accessing a WarehousePG with an API are:

1. Download your programming language platform and respective API from the appropriate source. For example, you can get the Java Development Kit (JDK) and JDBC API from Oracle.
2. Write your client application according to the API specifications. When programming your application, be aware of the SQL support in WarehousePG so you do not include any unsupported SQL syntax.

Download the appropriate driver and configure connectivity to your WarehousePG coordinator instance.

Parent topic: Accessing the Database

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4.2.3.7 Troubleshooting Connection Problems

A number of things can prevent a client application from successfully connecting to WarehousePG. This topic explains some of the common causes of connection problems and how to correct them.

Problem	Solution
No `pg_hba.conf` entry for host or user	To enable WarehousePG to accept remote client connections, you must configure your WarehousePG coordinator instance so that connections are allowed from the client hosts and database users that will be connecting to WarehousePG. This is done by adding the appropriate entries to the `pg_hba.conf` configuration file (located in the coordinator instance's data directory). For more detailed information, see Allowing Connections to WarehousePG.
WarehousePG is not running	If the WarehousePG coordinator instance is down, users will not be able to connect. You can verify that the WarehousePG cluster is up by running the `gpstate` utility on the WarehousePG coordinator host.
Network problems Interconnect timeouts	If users connect to the WarehousePG coordinator host from a remote client, network problems can prevent a connection (for example, DNS host name resolution problems, the host system is down, and so on.). To ensure that network problems are not the cause, connect to the WarehousePG coordinator host from the remote client host. For example: `ping hostname` If the system cannot resolve the host names and IP addresses of the hosts involved in WarehousePG, queries and connections will fail. For some operations, connections to the WarehousePG coordinator use `localhost` and others use the actual host name, so you must be able to resolve both. If you encounter this error, first make sure you can connect to each host in your WarehousePG cluster from the coordinator host over the network. In the `/etc/hosts` file of the coordinator and all segments, make sure you have the correct host names and IP addresses for all hosts involved in the WarehousePG cluster. The `127.0.0.1` IP must resolve to `localhost`.
Too many clients already	By default, WarehousePG is configured to allow a maximum of 250 concurrent user connections on the coordinator and 750 on a segment. A connection attempt that causes that limit to be exceeded will be refused. This limit is controlled by the `max_connections` parameter in the `postgresql.conf` configuration file of the WarehousePG coordinator. If you change this setting for the coordinator, you must also make appropriate changes at the segments.

Parent topic: Accessing the Database

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4.2.4 Configuring the WarehousePG cluster

Server configuration parameters affect the behavior of WarehousePG.They are part of the PostgreSQL "Grand Unified Configuration" system, so they are sometimes called "GUCs." Most of the WarehousePG server configuration parameters are the same as the PostgreSQL configuration parameters, but some are WarehousePG-specific.

- About WarehousePG Coordinator and Local Parameters
- Setting Configuration Parameters
- Viewing Server Configuration Parameter Settings
- Configuration Parameter Categories

Parent topic: Managing a WarehousePG cluster

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4.2.4.1 About WarehousePG Coordinator and Local Parameters

Server configuration files contain parameters that configure server behavior. The WarehousePG configuration file, postgresql.conf, resides in the data directory of the database instance.

The coordinator and each segment instance have their own postgresql.conf file. Some parameters are *local*: each segment instance examines its postgresql.conf file to get the value of that parameter. Set local parameters on the coordinator and on each segment instance.

Other parameters are *coordinator* parameters that you set on the coordinator instance. The value is passed down to (or in some cases ignored by) the segment instances at query run time.

See the *WarehousePG Reference Guide* for information about *local* and *coordinator* server configuration parameters.

Parent topic: Configuring the WarehousePG cluster

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4.2.4.2 Setting Configuration Parameters

Many configuration parameters limit who can change them and where or when they can be set. For example, to change certain parameters, you must be a WarehousePG superuser. Other parameters can be set only at the system level in the postgresql.conf file or require a system restart to take effect.

Many configuration parameters are *session* parameters. You can set session parameters at the system level, the database level, the role level or the session level. Database users can change most session parameters within their session, but some require superuser permissions.

See the *WarehousePG Reference Guide* for information about setting server configuration parameters.

- Setting a Local Configuration Parameter
- Setting a Coordinator Configuration Parameter

Parent topic: Configuring the WarehousePG cluster

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4.2.4.2.1 Setting a Local Configuration Parameter

To change a local configuration parameter across multiple segments, update the parameter in the `postgresql.conf` file of each targeted segment, both primary and mirror. Use the `gpconfig` utility to set a parameter in all WarehousePG `postgresql.conf` files. For example:

```
$ gpconfig -c gp_vmem_protect_limit -v 4096
```

Restart WarehousePG to make the configuration changes effective:

```
$ gpstop -r
```

Parent topic: Setting Configuration Parameters

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4.2.4.2.2 Setting a Coordinator Configuration Parameter

To set a coordinator configuration parameter, set it at the WarehousePG coordinator instance. If it is also a *session* parameter, you can set the parameter for a particular database, role or session. If a parameter is set at multiple levels, the most granular level takes precedence. For example, session overrides role, role overrides database, and database overrides system.

- Setting Parameters at the System Level
- Setting Parameters at the Database Level
- Setting Parameters at the Role Level
- Setting Parameters in a Session

Parent topic: Setting Configuration Parameters

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4.2.4.2.2.1 Setting Parameters at the System Level

Coordinator parameter settings in the coordinator `postgresql.conf` file are the system-wide default. To set a coordinator parameter:

1. Edit the `$COORDINATOR_DATA_DIRECTORY/postgresql.conf` file.
2. Find the parameter to set, uncomment it (remove the preceding `#` character), and type the desired value.
3. Save and close the file.
4. For *session* parameters that do not require a server restart, upload the `postgresql.conf` changes as follows:

   ```
   $ gpstop -u
   ```

5. For parameter changes that require a server restart, restart WarehousePG as follows:

   ```
   $ gpstop -r
   ```

For details about the server configuration parameters, see the *WarehousePG Reference Guide*.

Parent topic: Setting a Coordinator Configuration Parameter

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4.2.4.2.2.2 Setting Parameters at the Database Level

Use `ALTER DATABASE` to set parameters at the database level. For example:

```
=# ALTER DATABASE mydatabase SET search_path TO myschema;
```

When you set a session parameter at the database level, every session that connects to that database uses that parameter setting. Settings at the database level override settings at the system level.

Parent topic: Setting a Coordinator Configuration Parameter

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4.2.4.2.2.3 Setting Parameters at the Role Level

Use `ALTER ROLE` to set a parameter at the role level. For example:

```
=# ALTER ROLE bob SET search_path TO bobschema;
```

When you set a session parameter at the role level, every session initiated by that role uses that parameter setting. Settings at the role level override settings at the database level.

Parent topic: Setting a Coordinator Configuration Parameter

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4.2.4.2.2.4 Setting Parameters in a Session

Any session parameter can be set in an active database session using the `SET` command. For example:

```
=# SET statement_mem TO '200MB';
```

The parameter setting is valid for the rest of that session or until you issue a `RESET` command. For example:

```
=# RESET statement_mem;
```

Settings at the session level override those at the role level.

Parent topic: Setting a Coordinator Configuration Parameter

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4.2.4.3 Viewing Server Configuration Parameter Settings

The SQL command `SHOW` allows you to see the current server configuration parameter settings. For example, to see the settings for all parameters:

```
$ psql -c 'SHOW ALL;'
```

`SHOW` lists the settings for the coordinator instance only. To see the value of a particular parameter across the entire system (and all segments), use the `gpconfig` utility. For example:

```
$ gpconfig --show max_connections
```

Parent topic: Configuring the WarehousePG cluster

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4.2.4.4 Configuration Parameter Categories

Configuration parameters affect categories of server behaviors, such as resource consumption, query tuning, and authentication. Refer to Parameter Categories in the *WarehousePG Reference Guide* for a list of WarehousePG server configuration parameter categories.

Parent topic: Configuring the WarehousePG cluster

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4.2.5 Enabling Compression

You can configure WarehousePG to use data compression with some database features and with some utilities.Compression reduces disk usage and improves I/O across the system, however, it adds some performance overhead when compressing and decompressing data.

You can configure support for data compression with these features and utilities. See the specific feature or utility for information about support for compression.

- Append-optimized tables support compressing table data. See CREATE TABLE.
- User-defined data types can be defined to compress data. SeeCREATE TYPE.
- The external table protocols gpfdist (gpfdists), s3, and pxf support compression when accessing external data. For information about external tables, see CREATE EXTERNAL TABLE.
- Workfiles (temporary spill files that are created when running a query that requires more memory than it is allocated) can be compressed. See the server configuration parametergp_workfile_compression.
- The WarehousePG utilities `gpbackup`, `gprestore`, `gpload`, `gplogfilter` support compression.

For some compression algorithms (such as zstd) WarehousePG requires software packages installed on the host system. For information about required software packages, see the *WarehousePG Installation Guide*.

Parent topic: Managing a WarehousePG cluster

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4.2.6 Configuring Proxies for the WarehousePG Interconnect

You can configure a WarehousePG cluster to use proxies for interconnect communication to reduce the use of connections and ports during query processing.

The WarehousePG *interconnect* (the networking layer) refers to the inter-process communication between segments and the network infrastructure on which this communication relies. For information about the WarehousePG architecture and interconnect, see About the WarehousePG Architecture.

In general, when running a query, a QD (query dispatcher) on the WarehousePG coordinator creates connections to one or more QE (query executor) processes on segments, and a QE can create connections to other QEs. For a description of WarehousePG query processing and parallel query processing, see About WarehousePG Query Processing.

By default, connections between the QD on the coordinator and QEs on segment instances and between QEs on different segment instances require a separate network port. You can configure a WarehousePG cluster to use proxies when WarehousePG communicates between the QD and QEs and between QEs on different segment instances. The interconnect proxies require only one network connection for WarehousePG internal communication between two segment instances, so it consumes fewer connections and ports than `TCP` mode, and has better performance than `UDPIFC` mode in a high-latency network.

To enable interconnect proxies for the WarehousePG cluster, set these system configuration parameters.

- List the proxy ports with the parameter gp_interconnect_proxy_addresses. You must specify a proxy port for the coordinator, standby coordinator, and all segment instances.
- Set the parameter gp_interconnect_type to `proxy`.

> **Note** When expanding a WarehousePG cluster, you must deactivate interconnect proxies before adding new hosts and segment instances to the system, and you must update the `gp_interconnect_proxy_addresses` parameter with the newly-added segment instances before you re-enable interconnect proxies.

Parent topic: Managing a WarehousePG cluster

Example

This example sets up a WarehousePG cluster to use proxies for the WarehousePG interconnect when running queries. The example sets the gp_interconnect_proxy_addresses parameter and tests the proxies before setting the gp_interconnect_type parameter for the WarehousePG cluster.

- Setting the Interconnect Proxy Addresses
- Testing the Interconnect Proxies
- Setting Interconnect Proxies for the System

Setting the Interconnect Proxy Addresses

Set the `gp_interconnect_proxy_addresses` parameter to specify the proxy ports for the coordinator and segment instances. The syntax for the value has the following format and you must specify the parameter value as a single-quoted string.

```
<db_id>:<cont_id>:<seg_address>:<port>[, ... ]
```

For the coordinator, standby coordinator, and segment instance, the first three fields, db_id, cont_id, and seg_address can be found in the gp_segment_configuration catalog table. The fourth field, port, is the proxy port for the WarehousePG coordinator or a segment instance.

- db_id is the `dbid` column in the catalog table.
- cont_id is the `content` column in the catalog table.
- seg_address is the IP address or hostname corresponding to the `address` column in the catalog table.
- port is the TCP/IP port for the segment instance proxy that you specify.

> **Important** If a segment instance hostname is bound to a different IP address at runtime, you must run `gpstop -u` to re-load the `gp_interconnect_proxy_addresses` value.

This is an example PL/Python function that displays or sets the segment instance proxy port values for the `gp_interconnect_proxy_addresses` parameter. To create and run the function, you must enable PL/Python in the database with the `CREATE EXTENSION plpython3u` command.

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```
--
-- A PL/Python function to setup the interconnect proxy addresses.
-- Requires the Python modules os and socket.
--
-- Usage:
--   select my_setup_ic_proxy(-1000, '');              -- display IC proxy values for segments
--   select my_setup_ic_proxy(-1000, 'update proxy');  -- update the gp_interconnect_proxy_addresses parameter
--
-- The first argument, "delta", is used to calculate the proxy port with this formula:
--
--   proxy_port = postmaster_port + delta
--
-- The second argument, "action", is used to update the gp_interconnect_proxy_addresses parameter.
-- The parameter is not updated unless "action" is 'update proxy'.
-- Note that running  "gpstop -u" is required for the update to take effect.
-- A WarehousePG cluster restart will also work.
--
create or replace function my_setup_ic_proxy(delta int, action text)
returns table(dbid smallint, content smallint, address text, port int) as $$
    import os
    import socket

    results = []
    value = ''

    segs = plpy.execute('''SELECT dbid, content, port, address
                             FROM gp_segment_configuration
                            ORDER BY 1''')
    for seg in segs:
        dbid = seg['dbid']
        content = seg['content']
        port = seg['port']
        address = seg['address']

        # decide the proxy port
        port = port + delta

        # append to the result list
        results.append((dbid, content, address, port))

        # build the value for the GUC
        if value:
            value += ','
        value += '{}:{}:{}:{}'.format(dbid, content, address, port)

    if action.lower() == 'update proxy':
        os.system('''gpconfig --skipvalidation -c gp_interconnect_proxy_addresses -v "'{}'"'''.format(value))
        plpy.notice('''the settings are applied, please reload with 'gpstop -u' to take effect.''')
    else:
        plpy.notice('''if the settings are correct, re-run with 'update proxy' to apply.''')
    return results
$$ language plpython3u execute on coordinator;
```

> **Note** When you run the function, you should connect to the database using the WarehousePG interconnect type `UDPIFC` or `TCP`. This example uses `psql` to connect to the database `mytest` with the interconnect type `UDPIFC`.

```
PGOPTIONS="-c gp_interconnect_type=udpifc" psql -d mytest
```

Running this command lists the segment instance values for the `gp_interconnect_proxy_addresses` parameter.

```
select my_setup_ic_proxy(-1000, '');
```

This command runs the function to set the parameter.

```
select my_setup_ic_proxy(-1000, 'update proxy');
```

As an alternative, you can run the `gpconfig` utility to set the `gp_interconnect_proxy_addresses` parameter. To set the value as a string, the value is a single-quoted string that is enclosed in double quotes. The example WarehousePG cluster consists of a coordinator and a single segment instance.

```
gpconfig --skipvalidation -c gp_interconnect_proxy_addresses -v "'1:-1:192.168.180.50:35432,2:0:192.168.180.54:35000'"
```

After setting the `gp_interconnect_proxy_addresses` parameter, reload the `postgresql.conf` file with the `gpstop -u` command. This command does not stop and restart the WarehousePG cluster.

Testing the Interconnect Proxies

To test the proxy ports configured for the system, you can set the `PGOPTIONS` environment variable when you start a `psql` session in a command shell. This command sets the environment variable to enable interconnect proxies, starts `psql`, and logs into the database `mytest`.

```
PGOPTIONS="-c gp_interconnect_type=proxy" psql -d mytest
```

You can run queries in the shell to test the system. For example, you can run a query that accesses all the primary segment instances. This query displays the segment IDs and number of rows on the segment instance from the table `sales`.

```
# SELECT gp_segment_id, COUNT(*) FROM sales GROUP BY gp_segment_id ;
```

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Setting Interconnect Proxies for the System

After you have tested the interconnect proxies for the system, set the server configuration parameter for the system with the `gpconfig` utility.

```
gpconfig -c  gp_interconnect_type -v proxy
```

Reload the `postgresql.conf` file with the `gpstop -u` command. This command does not stop and restart the WarehousePG cluster.

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4.2.7 Enabling High Availability and Data Consistency Features

The fault tolerance and the high-availability features of WarehousePG can be configured.

> **Important** When data loss is not acceptable for a WarehousePG cluster, WarehousePG coordinator and segment mirroring is recommended. If mirroring is not enabled then WarehousePG stores only one copy of the data, so the underlying storage media provides the only guarantee for data availability and correctness in the event of a hardware failure.

For information about the utilities that are used to enable high availability, see the *WarehousePG Utility Guide*.

- Overview of WarehousePG High Availability
- Enabling Mirroring in WarehousePG
- How WarehousePG Detects a Failed Segment
- Understanding Segment Recovery
- Recovering from Segment Failures
- Recovering a Failed Coordinator

Parent topic: Managing a WarehousePG cluster

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4.2.7.1 Overview of WarehousePG High Availability

A WarehousePG cluster can be made highly available by providing a fault-tolerant hardware platform, by enabling WarehousePG high-availability features, and by performing regular monitoring and maintenance procedures to ensure the health of all system components.

Hardware components will eventually fail, whether due to normal wear or an unexpected circumstance. Loss of power can lead to temporarily unavailable components. A system can be made highly available by providing redundant standbys for components that can fail so that services can continue uninterrupted when a failure does occur. In some cases, the cost of redundancy is higher than users' tolerance for interruption in service. When this is the case, the goal is to ensure that full service is able to be restored, and can be restored within an expected timeframe.

With WarehousePG, fault tolerance and data availability is achieved with:

- Hardware level RAID storage protection
- Data storage checksums
- WarehousePG segment mirroring
- Coordinator mirroring
- Dual clusters
- Database backup and restore

Hardware level RAID

A best practice WarehousePG deployment uses hardware level RAID to provide high performance redundancy for single disk failure without having to go into the database level fault tolerance. This provides a lower level of redundancy at the disk level.

Data storage checksums

WarehousePG uses checksums to verify that data loaded from disk to memory has not been corrupted on the file system.

WarehousePG has two kinds of storage for user data: heap and append-optimized. Both storage models use checksums to verify data read from the file system and, with the default settings, they handle checksum verification errors in a similar way.

WarehousePG coordinator and segment database processes update data on pages in the memory they manage. When a memory page is updated and flushed to disk, checksums are computed and saved with the page. When a page is later retrieved from disk, the checksums are verified and the page is only permitted to enter managed memory if the verification succeeds. A failed checksum verification is an indication of corruption in the file system and causes WarehousePG to generate an error, cancelling the transaction.

The default checksum settings provide the best level of protection from undetected disk corruption propagating into the database and to mirror segments.

Heap checksum support is enabled by default when the WarehousePG cluster is initialized with the `gpinitsystem` management utility. Although it is strongly discouraged, a cluster can be initialized without heap checksum support by setting the `HEAP_CHECKSUM` parameter to off in the `gpinitsystem` cluster configuration file. See gpinitsystem.

Once initialized, it is not possible to change heap checksum support for a cluster without reinitializing the system and reloading databases.

You can check the read-only server configuration parameter data_checksums to see if heap checksums are enabled in a cluster:

```
$ gpconfig -s data_checksums
```

When a WarehousePG cluster starts up, the `gpstart` utility checks that heap checksums are consistently enabled or deactivated on the coordinator and all segments. If there are any differences, the cluster fails to start. Seegpstart.

In cases where it is necessary to ignore heap checksum verification errors so that data can be recovered, setting theignore_checksum_failure system configuration parameter to on causes WarehousePG to issue a warning when a heap checksum verification fails, but the page is then permitted to load into managed memory. If the page is updated and saved to disk, the corrupted data could be replicated to the mirror segment. Because this can lead to data loss, setting `ignore_checksum_failure` to on should only be done to enable data recovery.

For append-optimized storage, checksum support is one of several storage options set at the time an append-optimized table is created with the `CREATE TABLE` command. The default storage options are specified in the `gp_default_storage_options` server configuration parameter. The `checksum` storage option is activated by default and deactivating it is strongly discouraged.

If you choose to deactivate checksums for an append-optimized table, you can either

- change the `gp_default_storage_options` configuration parameter to include `checksum=false` before creating the table, or
- add the `checksum=false` option to the `WITH storage\_options` clause of the `CREATE TABLE` statement.

Note that the `CREATE TABLE` statement allows you to set storage options, including checksums, for individual partition files.

See the CREATE TABLE command reference and the gp_default_storage_options configuration parameter reference for syntax and examples.

Segment Mirroring

WarehousePG stores data in multiple segment instances, each of which is a WarehousePG PostgreSQL instance. The data for each table is spread between the segments based on the distribution policy that is defined for the table in the DDL at the time the table is created. When segment mirroring is enabled, for each segment instance there is a *primary* and *mirror* pair. The mirror segment is kept up to date with the primary segment using Write-Ahead Logging (WAL)-based streaming replication. See Overview of Segment Mirroring.

The mirror instance for each segment is usually initialized with the `gpinitsystem` utility or the `gpexpand` utility. As a best practice, the mirror runs on a different host than the primary instance to protect from a single machine failure. There are different strategies for assigning mirrors to hosts. When choosing the layout of the primaries and mirrors, it is important to consider the failure scenarios to ensure that processing skew is minimized in the case of a single machine failure.

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Coordinator Mirroring

There are two coordinator instances in a highly available cluster, a *primary* and a *standby*. As with segments, the coordinator and standby should be deployed on different hosts so that the cluster can tolerate a single host failure. Clients connect to the primary coordinator and queries can be run only on the primary coordinator. The standby coordinator is kept up to date with the primary coordinator using Write-Ahead Logging (WAL)-based streaming replication. See Overview of Coordinator Mirroring.

If the coordinator fails, the administrator runs the `gpactivatestandby` utility to have the standby coordinator take over as the new primary coordinator. You can configure a virtual IP address for the coordinator and standby so that client programs do not have to switch to a different network address when the current coordinator changes. If the coordinator host fails, the virtual IP address can be swapped to the actual acting coordinator.

Dual Clusters

An additional level of redundancy can be provided by maintaining two WarehousePG clusters, both storing the same data.

Two methods for keeping data synchronized on dual clusters are "dual ETL" and "backup/restore."

Dual ETL provides a complete standby cluster with the same data as the primary cluster. ETL (extract, transform, and load) refers to the process of cleansing, transforming, validating, and loading incoming data into a data warehouse. With dual ETL, this process is run twice in parallel, once on each cluster, and is validated each time. It also allows data to be queried on both clusters, doubling the query throughput. Applications can take advantage of both clusters and also ensure that the ETL is successful and validated on both clusters.

To maintain a dual cluster with the backup/restore method, create backups of the primary cluster and restore them on the secondary cluster. This method takes longer to synchronize data on the secondary cluster than the dual ETL strategy, but requires less application logic to be developed. Populating a second cluster with backups is ideal in use cases where data modifications and ETL are performed daily or less frequently.

Backup and Restore

Making regular backups of the databases is recommended except in cases where the database can be easily regenerated from the source data. Backups should be taken to protect from operational, software, and hardware errors.

Use the `gpbackup` utility to backup WarehousePG. `gpbackup` performs the backup in parallel across segments, so backup performance scales up as hardware is added to the cluster.

When designing a backup strategy, a primary concern is where to store the backup data. The data each segment manages can be backed up on the segment's local storage, but should not be stored there permanently—the backup reduces disk space available to the segment and, more importantly, a hardware failure could simultaneously destroy the segment's live data and the backup. After performing a backup, the backup files should be moved from the primary cluster to separate, safe storage. Alternatively, the backup can be made directly to separate storage.

Using a WarehousePG storage plugin with the `gpbackup` and `gprestore` utilities, you can send a backup to, or retrieve a backup from a remote location or a storage appliance. WarehousePG storage plugins support connecting to locations including Amazon Simple Storage Service (Amazon S3) compatbile locations such as Cloudian and Minio.

Using the Backup/Restore Storage Plugin API you can create a custom plugin that the `gpbackup` and `gprestore` utilities can use to integrate a custom backup storage system with the WarehousePG.

For information about using `gpbackup` and `gprestore`, see the documentation.

- **Overview of Segment Mirroring**
- **Overview of Coordinator Mirroring**

Parent topic: Enabling High Availability and Data Consistency Features

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4.2.7.2 Enabling Mirroring in WarehousePG

You can configure your WarehousePG cluster with mirroring at setup time using `gpinitsystem` or enable mirroring later using `gpaddmirrors` and `gpinitstandby`. This topic assumes you are adding mirrors to an existing system that was initialized without mirrors.

- Enabling Segment Mirroring
- Enabling Coordinator Mirroring

Parent topic: Enabling High Availability and Data Consistency Features

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4.2.7.2.1 Enabling Segment Mirroring

Mirror segments allow database queries to fail over to a backup segment if the primary segment is unavailable. By default, mirrors are configured on the same array of hosts as the primary segments. You may choose a completely different set of hosts for your mirror segments so they do not share machines with any of your primary segments.

> **Important** During the online data replication process, WarehousePG should be in a quiescent state, workloads and other queries should not be running.

To add segment mirrors to an existing system (same hosts as primaries)

1. Allocate the data storage area for mirror data on all segment hosts. The data storage area must be different from your primary segments' file system location.
2. Use gpssh-exkeys to ensure that the segment hosts can SSH and remote sync to each other without a password prompt.
3. Run the gpaddmirrors utility to enable mirroring in your WarehousePG cluster. For example, to add 10000 to your primary segment port numbers to calculate the mirror segment port numbers:

   ```
   $ gpaddmirrors -p 10000
   ```

   Where `-p` specifies the number to add to your primary segment port numbers. Mirrors are added with the default group mirroring configuration.

To add segment mirrors to an existing system (different hosts from primaries)

1. Ensure the WarehousePG software is installed on all hosts. See the *WarehousePG Installation Guide* for detailed installation instructions.
2. Allocate the data storage area for mirror data, and tablespaces if needed, on all segment hosts.
3. Use `gpssh-exkeys` to ensure the segment hosts can SSH and remote sync to each other without a password prompt.
4. Create a configuration file that lists the host names, ports, and data directories on which to create mirrors. To create a sample configuration file to use as a starting point, run:

   ```
   $ gpaddmirrors -o <filename>
   ```

   The format of the mirror configuration file is:

   ```
   <row_id>=<contentID>|<address>|<port>|<data_dir>
   ```

   Where `row_id` is the row in the file, contentID is the segment instance content ID, address is the host name or IP address of the segment host, port is the communication port, and `data_dir` is the segment instance data directory.

   For example, this is contents of a mirror configuration file for two segment hosts and two segment instances per host:

   ```
   0=2|sdw1-1|41000|/data/mirror1/gp2
   1=3|sdw1-2|41001|/data/mirror2/gp3
   2=0|sdw2-1|41000|/data/mirror1/gp0
   3=1|sdw2-2|41001|/data/mirror2/gp1
   ```

5. Run the `gpaddmirrors` utility to enable mirroring in your WarehousePG cluster:

   ```
   $ gpaddmirrors -i <mirror_config_file>
   ```

   The `-i` option specifies the mirror configuration file you created.

Parent topic: Enabling Mirroring in WarehousePG

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4.2.7.2.2 Enabling Coordinator Mirroring

You can configure a new WarehousePG cluster with a standby coordinator using `gpinitsystem` or enable it later using `gpinitstandby`. This topic assumes you are adding a standby coordinator to an existing system that was initialized without one.

For information about the utilities gpinitsystem and gpinitstandby, see the *WarehousePG Utility Guide*.

To add a standby coordinator to an existing system

1. Ensure the standby coordinator host is installed and configured: `gpadmin` system user created, WarehousePG binaries installed, environment variables set, SSH keys exchanged, and that the data directories and tablespace directories, if needed, are created.
2. Run the `gpinitstandby` utility on the currently active *primary* coordinator host to add a standby coordinator host to your WarehousePG cluster. For example:

   ```
   $ gpinitstandby -s scdw
   ```

   Where `-s` specifies the standby coordinator host name.

To switch operations to a standby coordinator, see Recovering a Failed Coordinator.

To check the status of the coordinator mirroring process (optional)

You can run the `gpstate` utility with the `-f` option to display details of the standby coordinator host.

```
$ gpstate -f
```

The standby coordinator status should be passive, and the WAL sender state should be streaming.

For information about the gpstate utility, see the *WarehousePG Utility Guide*.

Parent topic: Enabling Mirroring in WarehousePG

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4.2.7.3 How WarehousePG Detects a Failed Segment

With segment mirroring enabled, WarehousePG automatically fails over to a mirror segment instance when a primary segment instance goes down. Provided one segment instance is online per portion of data, users may not realize a segment is down. If a transaction is in progress when a fault occurs, the in-progress transaction rolls back and restarts automatically on the reconfigured set of segments. The gpstate utility can be used to identify failed segments. The utility displays information from the catalog tables including gp_segment_configuration.

If the entire WarehousePG system becomes nonoperational due to a segment failure (for example, if mirroring is not enabled or not enough segments are online to access all user data), users will see errors when trying to connect to a database. The errors returned to the client program may indicate the failure. For example:

```
ERROR: All segment databases are unavailable
```

How a Segment Failure is Detected and Managed

On the WarehousePG coordinator host, the Postgres `postmaster` process forks a fault probe process, `ftsprobe`. This is also known as the FTS (Fault Tolerance Server) process. The `postmaster` process restarts the FTS if it fails.

The FTS runs in a loop with a sleep interval between each cycle. On each loop, the FTS probes each primary segment instance by making a TCP socket connection to the segment instance using the hostname and port registered in the `gp_segment_configuration` table. If the connection succeeds, the segment performs a few simple checks and reports back to the FTS. The checks include running a `stat` system call on critical segment directories and checking for internal faults in the segment instance. If no issues are detected, a positive reply is sent to the FTS and no action is taken for that segment instance.

If the connection cannot be made, or if a reply is not received in the timeout period, then a retry is attempted for the segment instance. If the configured maximum number of probe attempts fail, the FTS probes the segment's mirror to ensure that it is up, and then updates the `gp_segment_configuration` table, marking the primary segment "down" and setting the mirror to act as the primary. The FTS updates thegp_configuration_history table with the operations performed.

When there is only an active primary segment and the corresponding mirror is down, the primary goes into the *Not In Sync* state and continues logging database changes, so the mirror can be synchronized without performing a full copy of data from the primary to the mirror.

Configuring FTS Behavior

There is a set of server configuration parameters that affect FTS behavior:

gp_fts_probe_interval How often, in seconds, to begin a new FTS loop. For example if the setting is 60 and the probe loop takes 10 seconds, the FTS process sleeps 50 seconds. If the setting is 60 and probe loop takes 75 seconds, the process sleeps 0 seconds. The default is 60, and the maximum is 3600.

gp_fts_probe_timeout Probe timeout between coordinator and segment, in seconds. The default is 20, and the maximum is 3600.

gp_fts_probe_retries The number of attempts to probe a segment. For example if the setting is 5 there will be 4 retries after the first attempt fails. Default: 5

gp_log_fts Logging level for FTS. The value may be "off", "terse", "verbose", or "debug". The "verbose" setting can be used in production to provide useful data for troubleshooting. The "debug" setting should not be used in production. Default: "terse"

gp_segment_connect_timeout The maximum time (in seconds) allowed for a mirror to respond. Default: 180 (3 minutes)

In addition to the fault checking performed by the FTS, a primary segment that is unable to send data to its mirror can change the status of the mirror to down. The primary queues up the data and after `gp_segment_connect_timeout` seconds pass, indicates a mirror failure, causing the mirror to be marked down and the primary to go into `Not In Sync` mode.

- Checking for Failed Segments

Parent topic: Enabling High Availability and Data Consistency Features

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4.2.7.4 Understanding Segment Recovery

This topic provides background information about concepts and principles of segment recovery. If you have down segments and need immediate help recovering them, see the instructions inRecovering from Segment Failures. For information on how WarehousePG detects that segments are down and an explanation of the Fault Tolerance Server (FTS) that manages down segment tracking, see How WarehousePG Detects a Failed Segment.

This topic is divided into the following sections:

- Segment Recovery Basics
- Segment Recovery: Flow of Events
- Simple Failover and Recovery Example
- The Three Types of Segment Recovery

Parent topic: Enabling High Availability and Data Consistency Features

Segment Recovery Basics

If the coordinator cannot connect to a segment instance, it marks that segment as down in the WarehousePG `gp_segment_configuration` table. The segment instance remains offline until an administrator takes steps to bring the segment back online. The process for recovering a down segment instance or host depends on the cause of the failure and on whether or not mirroring is enabled. A segment instance can be marked as down for a number of reasons:

- A segment host is unavailable; for example, due to network or hardware failures.
- A segment instance is not running; for example, there is no `postgres` database listener process.
- The data directory of the segment instance is corrupt or missing; for example, data is not accessible, the file system is corrupt, or there is a disk failure.

In order to bring the down segment instance back into operation again, you must correct the problem that made it fail in the first place, and then – if you have mirroring enabled – you can attempt to recover the segment instance from its mirror using the `gprecoverseg` utility. See The Three Types of Segment Recovery, below, for details on the three possible ways to recover a downed segment's data.

Segment Recovery: Flow of Events

When a Primary Segment Goes Down

The following summarizes the flow of events that follow a **primary** segment going down:

1. A primary segment goes down.
2. The Fault Tolerance Server (FTS) detects this and marks the segment as down in the `gp_segment_configuration` table.
3. The mirror segment is promoted to primary and starts functioning as primary. The previous primary is demoted to mirror.
4. The user fixes the underlying problem.
5. The user runs `gprecoverseg` to bring back the (formerly primary) mirror segment.
6. The WAL synchronization process ensures that the mirror segment data is synchronized with the primary segment data. Users can check the state of this synching with `gpstate -e`.
7. WarehousePG marks the segments as up (`u`) in the `gp_segment_configuration` table.
8. If segments are not in their preferred roles, user runs `gprecoverseg -r` to restore them to their preferred roles.

When a Mirror Segment Goes Down

The following summarizes the flow of events that follow a **mirror** segment going down:

1. A mirror segment goes down.
2. The Fault Tolerance Server (FTS) detects this and marks the segment as down in the `gp_segment_configuration` table.
3. The user fixes the underlying problem.
4. The user runs `gprecoverseg` to bring back the (formerly mirror) mirror segment.
5. The synching process occurs: the mirror comes into sync with its primary via WAL synching. You can check the state of this synching with `gpstate -e`.

Rebalancing After Recovery

After a segment instance has been recovered, the segments may not be in their preferred roles, which can cause processing to be skewed. The `gp_segment_configuration` table has the columns `role` (current role) and `preferred_role` (original role at the beginning). When a segment's `role` and `preferred_role` do not match the system may not be balanced. To rebalance the cluster and bring all the segments into their preferred roles, run the `gprecoverseg -r` command.

Simple Failover and Recovery Example

Consider a single primary-mirror segment instance pair where the primary segment has failed over to the mirror. The following table shows the segment instance preferred role, role, mode, and status from the `gp_segment_configuration` table before beginning recovery of the failed primary segment.

You can also run `gpstate -e` to display any issues with a primary or mirror segment instances.

Segment Type	`preferred_role`	`role`	`mode`	`status`
Primary	`p` (primary)	`m` (mirror)	`n` (Not In Sync)	`d` (down)
Mirror	`m` (mirror)	`p` (primary)	`n` (Not In Sync)	`u` (up)

The primary segment is down and segment instances are not in their preferred roles. The mirror segment is up and its role is now primary. However, it is not synchronized with its mirror (the former primary segment) because that segment is down. You must potentially fix either issues with the host the down segment is running on, issues with the segment instance itself, or both. You then use `gprecoverseg` to prepare failed segment instances for recovery and initiate synchronization between the primary and mirror instances.

After `gprecoverseg` has completed, the segments are in the states shown in the following table where the primary-mirror segment pair is up with the primary and mirror roles reversed from their preferred roles.

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> **Note** There might be a lag between when `gprecoverseg` completes and when the segment status is set to `u` (up).

Segment Type	`preferred_role`	`role`	`mode`	`status`
Primary	`p` (primary)	`m` (mirror)	`s` (Synchronized)	`u` (up)
Mirror	`m` (mirror)	`p` (primary)	`s` (Synchronized)	`u` (up)

The `gprecoverseg -r` command rebalances the system by returning the segment roles to their preferred roles.

Segment Type	`preferred_role`	`role`	`mode`	`status`
Primary	`p` (primary)	`p` (primary)	`s` (Synchronized)	`u` (up)
Mirror	`m` (mirror)	`m` (mirror)	`s` (Synchronized)	`u` (up)

The Three Types of Segment Recovery

WarehousePG can perform three types of segment recovery: full, differential, and incremental (the default).

Full recovery : Full recovery recovers all segments. Specifically, it erases all data files and directories on the current mirror segment and copies to the mirror segment the exact contents of the current primary segment. Full recovery uses the `pg_basebackup` utility to copy files.

With full recovery, you may recover:

- to the current host -- known as "in-place recovery"
- to a different host within the current cluster
- to a new host outside of the current cluster

Differential recovery Differential recovery performs a filesystem-level diff between the primary and mirror segments, and copies from the primary to the mirror only those files that have changed on the primary. With differential recovery, you may only do in-place recovery. Differential recovery uses the `rsync` command to copy files.

Incremental recovery (default) Incremental recovery brings the mirror segment contents into sync with the primary segment contents with the aid of write-ahead log files (WAL files). With incremental recovery, you may only do in-place recovery. Incremental recovery uses the `pg_rewind` utility to copy files.

```
By default, `gprecoverseg` performs an incremental recovery, placing the mirror into *Synchronizing* mode, which starts to replay the recorded changes from the primary onto the mirror. If the incremental recovery cannot be completed, the recovery fails and you should run `gprecoverseg` again with the `-F` option, to perform full recovery. This causes the primary to copy all of its data to the mirror.

>**Note**
>After a failed incremental recovery attempt you must perform a full recovery.

Whenever possible, you should perform an incremental recovery rather than a full recovery, as incremental recovery is substantially faster. If you **do** need to perform an in-place full recovery, you can speed up in-place full recovery with `gprecoverseg`'s `--differential` option, which causes `gprecoverseg` to skip recovery of any files and directories that are unchanged.
```

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4.2.7.5 Recovering from Segment Failures

This topic walks you through what to do when one or more segments or hosts are down and you want to recover the down segments. The recovery path you follow depends primarily which of these 3 scenarios fits your circumstances:

- you want to recover in-place to the current host
- you want to recover to a different host, within the cluster
- you want to recover to a new host, outside of the cluster

The steps you follow within these scenarios can vary, depending on:

- whether you want to do an incremental or a full recovery
- whether you want to recover all segments or just a subset of segments

> **Note** Incremental recovery is only possible when recovering segments to the current host (in-place recovery).

This topic is divided into the following sections:

- Prerequisites
- Recovery Scenarios
- Post-Recovery Tasks

Parent topic: Enabling High Availability and Data Consistency Features

Prerequisites

- Mirroring is enabled for all segments.
- You've already identified which segments have failed. If necessary, see the topic Checking for Failed Segments.
- The coordinator host can connect to the segment host.
- All networking or hardware issues that caused the segment to fail have been resolved.

Recovery Scenarios

This section documents the steps for the 3 distinct segment recovery scenarios. Follow the link to instructions that walk you through each scenario.

- Recover In-Place to Current Host
  - Incremental Recovery
  - Full Recovery
  - Differential Recovery
- Recover to A Different Host within the Cluster
- Recover to A New Host, Outside of the Cluster

Recover In-Place to Current Host

When recovering in-place to the current host, you may choose between incremental recovery (the default), full recovery, and differential recovery.

Incremental Recovery

Follow these steps for incremental recovery:

1. To recover all segments, run `gprecoverseg` with no options:

   ```
   gprecoverseg
   ```

2. To recover a subset of segments:

   1. Manually create a `recover_config_file` file in a location of your choice, where each segment to recover has its own line with format `failedAddress|failedPort|failedDataDirectory` or `failedHostname|failedAddress|failedPort|failedDataDirectory`

      For multiple segments, create a new line for each segment you want to recover, specifying the hostname (optional), the address, port number and data directory for each down segment. For example:

      ```
      failedAddress1|failedPort1|failedDataDirectory1
      failedAddress2|failedPort2|failedDataDirectory2
      failedAddress3|failedPort3|failedDataDirectory3
      ```

      or

      ```
      failedHostname1|failedAddress1|failedPort1|failedDataDirectory1
      failedHostname2|failedAddress2|failedPort2|failedDataDirectory2
      failedHostname3|failedAddress3|failedPort3|failedDataDirectory3
      ```

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2. Alternatively, generate a sample recovery file using the following command; you may edit the resulting file if necessary:

   ```
   $ gprecoverseg -o /home/gpadmin/recover_config_file
   ```

3. Pass the `recover_config_file` to the `gprecoverseg -i` command:

   ```
   $ gprecoverseg -i /home/gpadmin/recover_config_file
   ```

3. Perform the post-recovery tasks summarized in the section Post-Recovery Tasks.

Full Recovery

1. To recover all segments, run `gprecoverseg -F`:

   ```
   gprecoverseg -F
   ```

2. To recover specific segments:

   1. Manually create a `recover_config_file` file in a location of your choice, where each segment to recover has its own line with following format:

      ```
      failedAddress1|failedPort1|failedDataDirectory1<SPACE>failedAddress2|failedPort2|failedDataDirectory2
      ```

      or

      ```
      failedHostname1|failedAddress1|failedPort1|failedDataDirectory1<SPACE>failedHostname2|failedAddress2|failedPort2|failedDataDirectory2
      ```

      Note the literal **SPACE** separating the lines.

   2. Alternatively, generate a sample recovery file using the following command and edit the resulting file to match your desired recovery configuration:

      ```
      $ gprecoverseg -o /home/gpadmin/recover_config_file
      ```

   3. Run the following command, passing in the config file generated in the previous step:

      ```
      $ gprecoverseg -i recover_config_file
      ```

3. Perform the post-recovery tasks summarized in the section Post-Recovery Tasks.

Differential Recovery

Follow these steps for differential recovery:

1. Run `gprecoverseg --differential`

Recover to A Different Host within the Cluster

> **Note** Only full recovery is possible when recovering to a different host in the cluster.

Follow these steps to recover all segments or just a subset of segments to a different host in the cluster:

1. Manually create a `recover_config_file` file in a location of your choice, where each segment to recover has its own line with following format:

   ```
   failedAddress|failedPort|failedDataDirectory<SPACE>newAddress|newPort|newDataDirectory
   ```

   or

   ```
   failedHostname|failedAddress|failedPort|failedDataDirectory<SPACE>newHostname|newAddress|newPort|newDataDirectory
   ```

   Note the literal **SPACE** separating the details of the down segment from the details of where the segment will be recovered to.

   Alternatively, generate a sample recovery file using the following command and edit the resulting file to match your desired recovery configuration:

   ```
   $ gprecoverseg -o -p /home/gpadmin/recover_config_file
   ```

2. Run the following command, passing in the config file generated in the previous step:

   ```
   $ gprecoverseg -i recover_config_file
   ```

3. Perform the post-recovery tasks summarized in the section Post-Recovery Tasks.

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Recover to A New Host, Outside of the Cluster

Follow these steps if you are planning to do a hardware refresh on the host the segments are running on.

> **Note** Only full recovery is possible when recovering to a new host.

Requirements for New Host

The new host must:

- have the same WarehousePG software installed and configured as the failed host
- have the same hardware and OS configuration as the failed host (same hostname, OS version, OS configuration parameters applied, locales, gpadmin user account, data directory locations created, ssh keys exchanged, number of network interfaces, network interface naming convention, and so on)
- have sufficient disk space to accommodate the segments
- be able to connect password-less with all other existing segments and WarehousePG coordinator.

Steps to Recover to a New Host

1. Bring up the new host
2. Run the following command to recover all segments to the new host:

   ```
   gprecoverseg -p <new_host_name>
   ```

   You may also specify more than one host. However, be sure you do not trigger a double-fault scenario when recovering to two hosts at a time.

   ```
   gprecoverseg -p <new_host_name1>,<new_host_name2>
   ```

   > **Note** In the case of multiple failed segment hosts, you can specify the hosts to recover to with a comma-separated list. However, it is strongly recommended to recover to one host at a time. If you must recover to more than one host at a time, then it is critical to ensure that a double fault scenario does not occur, in which both the segment primary and corresponding mirror are offline.

3. Perform the post-recovery tasks summarized in the section Post-Recovery Tasks.

Post-Recovery Tasks

Follow these steps once `gprecoverseg` has completed:

1. Validate segement status and preferred roles:

   ```
   select * from gp_segment_configuration
   ```

2. Monitor mirror synchronization progress:

   ```
   gpstate -e
   ```

3. If necessary, run the following command to return segments to their preferred roles:

   ```
   gprecoverseg -r
   ```

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4.2.7.6 Recovering a Failed Coordinator

If the primary coordinator fails, the WarehousePG cluster is not accessible and WAL replication stops. Use gpactivatestandby to activate the standby coordinator. Upon activation of the standby coordinator, WarehousePG reconstructs the coordinator host state at the time of the last successfully committed transaction.

These steps assume a standby coordinator host is configured for the system. See Enabling Coordinator Mirroring.

To activate the standby coordinator

1. Run the `gpactivatestandby` utility from the standby coordinator host you are activating. For example:

   ```
   $ export PGPORT=5432
   $ gpactivatestandby -d /data/coordinator/gpseg-1
   ```

   Where `-d` specifies the data directory of the coordinator host you are activating.

   After you activate the standby, it becomes the *active* or *primary* coordinator for your WarehousePG cluster.

   > **NOTE** Before running `gpactivatestandby`, be sure to run `gpstate -f` to confirm that the standby coordinator is synchronized with the current coordinator node. If synchronized, the final line of the `gpstate -f` output will look similar to this: `20230607:06:50:06:004205 gpstate:test1-m:gpadmin-[INFO]:--Sync state: sync`

2. After the utility completes, run `gpstate` with the `-b` option to display a summary of the system status:

   ```
   $ gpstate -b
   ```

   The coordinator instance status should be `Active`. When a standby coordinator is not configured, the command displays `No coordinator standby configured` for the standby coordinator status. If you configured a new standby coordinator, its status is `Passive`.

3. Optional: If you have not already done so while activating the prior standby coordinator, you can run `gpinitstandby` on the active coordinator host to configure a new standby coordinator.

   > **Important** You must initialize a new standby coordinator to continue providing coordinator mirroring.

   For information about restoring the original coordinator and standby coordinator configuration, see Restoring Coordinator Mirroring After a Recovery.

- **Restoring Coordinator Mirroring After a Recovery**

Parent topic: Enabling High Availability and Data Consistency Features

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4.2.7.7 Checking for Failed Segments

With mirroring enabled, you can have failed segment instances in the system without interruption of service or any indication that a failure has occurred. You can verify the status of your system using the `gpstate` utility, by examing the contents of the `gp_segment_configuration` catalog table, or by checking log files.

Check for failed segments using gpstate

The `gpstate` utility provides the status of each individual component of a WarehousePG cluster, including primary segments, mirror segments, coordinator, and standby coordinator.

On the coordinator host, run the gpstate utility with the `-e` option to show segment instances with error conditions:

```
$ gpstate -e
```

If the utility lists `Segments with Primary and Mirror Roles Switched`, the segment is not in its *preferred role* (the role to which it was assigned at system initialization). This means the system is in a potentially unbalanced state, as some segment hosts may have more active segments than is optimal for top system performance.

Segments that display the `Config status` as `Down` indicate the corresponding mirror segment is down.

See Recovering from Segment Failures for instructions to fix this situation.

Check for failed segments using the gp_segment_configuration table

To get detailed information about failed segments, you can check the gp_segment_configuration catalog table. For example:

```
$ psql postgres -c "SELECT * FROM gp_segment_configuration WHERE status='d';"
```

For failed segment instances, note the host, port, preferred role, and data directory. This information will help determine the host and segment instances to troubleshoot. To display information about mirror segment instances, run:

```
$ gpstate -m
```

Check for failed segments by examining log files

Log files can provide information to help determine an error's cause. The coordinator and segment instances each have their own log file in `log` of the data directory. The coordinator log file contains the most information and you should always check it first.

Use the gplogfilter utility to check the WarehousePG log files for additional information. To check the segment log files, run `gplogfilter` on the segment hosts using gpssh.

To check the log files

1. Use `gplogfilter` to check the coordinator log file for `WARNING`, `ERROR`, `FATAL` or `PANIC` log level messages:

   ```
   $ gplogfilter -t
   ```

2. Use `gpssh` to check for `WARNING`, `ERROR`, `FATAL`, or `PANIC` log level messages on each segment instance. For example:

   ```
   $ gpssh -f seg_hosts_file -e 'source
   /usr/edb/whpg7/greenplum_path.sh ; gplogfilter -t
   /data1/primary/*/log/gpdb*.log' > seglog.out
   ```

Parent topic: How WarehousePG Detects a Failed Segment

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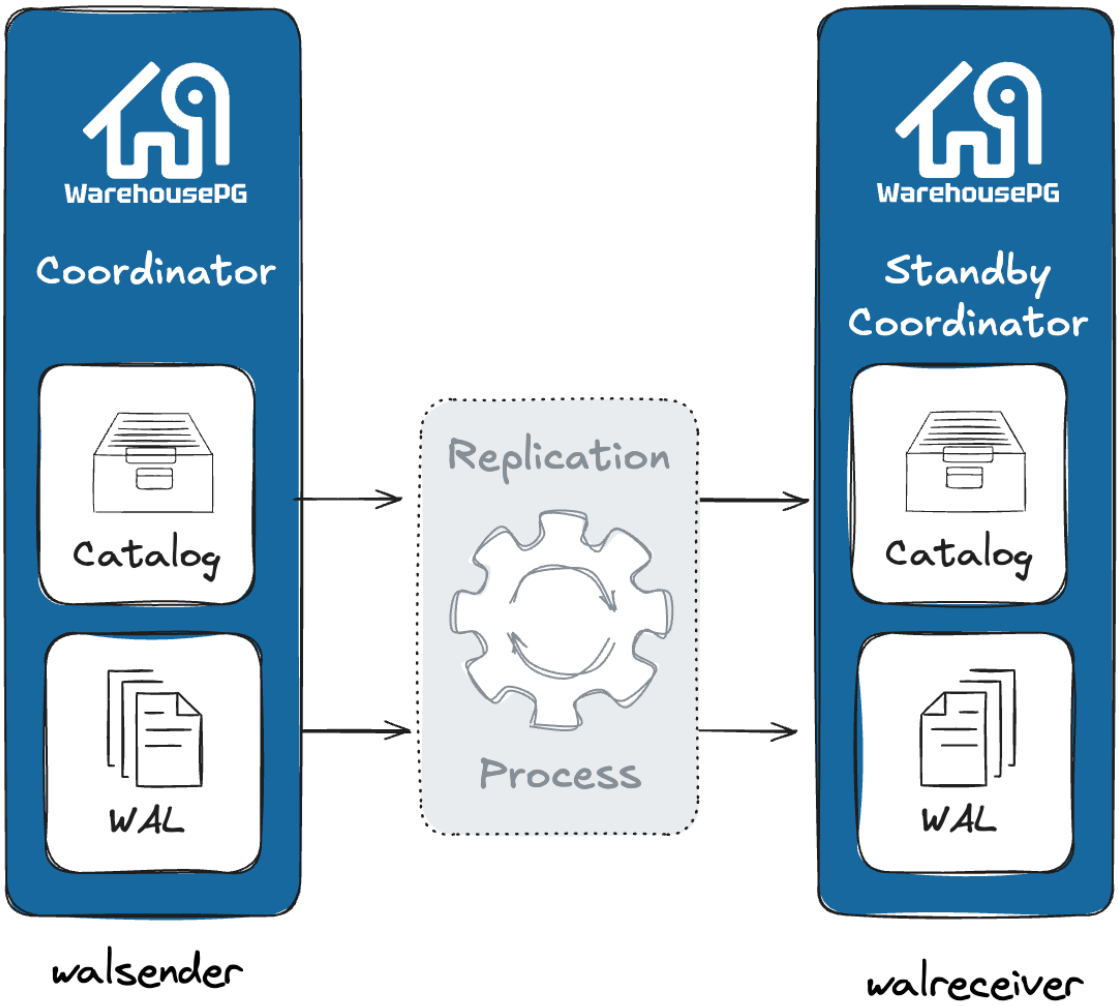
4.2.7.8 Overview of Coordinator Mirroring

You can deploy a backup or mirror of the coordinator instance on a separate host machine. The backup coordinator instance, called the *standby coordinator*, serves as a warm standby if the primary coordinator becomes nonoperational. You create a standby coordinator from the primary coordinator while the primary is online.

When you enable coordinator mirroring for an existing system, the primary coordinator continues to provide service to users while a snapshot of the primary coordinator instance is taken. While the snapshot is taken and deployed on the standby coordinator, changes to the primary coordinator are also recorded. After the snapshot has been deployed on the standby coordinator, the standby coordinator is synchronized and kept current using Write-Ahead Logging (WAL)-based streaming replication. WarehousePG WAL replication uses the `walsender` and `walreceiver` replication processes. The `walsender` process is a primary coordinator process. The `walreceiver` is a standby coordinator process.



Since the coordinator does not house user data, only system catalog tables are synchronized between the primary and standby coordinators. When these tables are updated, the replication logs that capture the changes are streamed to the standby coordinator to keep it current with the primary. During WAL replication, all database modifications are written to replication logs before being applied, to ensure data integrity for any in-process operations.

This is how WarehousePG handles a coordinator failure.

- If the primary coordinator fails, the WarehousePG cluster shuts down and the coordinator replication process stops. The administrator runs the `gpactivatestandby` utility to have the standby coordinator take over as the new primary coordinator. Upon activation of the standby coordinator, the replicated logs reconstruct the state of the primary coordinator at the time of the last successfully committed transaction. The activated standby coordinator then functions as the WarehousePG coordinator, accepting connections on the port specified when standby coordinator was initialized. See Recovering a Failed Coordinator.
- If the standby coordinator fails or becomes inaccessible while the primary coordinator is active, the primary coordinator tracks database changes in logs that are applied to the standby coordinator when it is recovered.

These WarehousePG cluster catalog tables contain mirroring and replication information.

- The catalog table gp_segment_configuration contains the current configuration and state of primary and mirror segment instances and the coordinator and standby coordinator instance.
- The catalog view gp_stat_replication contains replication statistics of the `walsender` processes that are used for WarehousePG coordinator and segment mirroring.

Parent topic: Overview of WarehousePG High Availability

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4.2.7.9 Overview of Segment Mirroring

When WarehousePG High Availability is enabled, there are two types of segment instances: *primary* and *mirror*. Each primary segment has one corresponding mirror segment. A primary segment instance receives requests from the coordinator to make changes to the segment data and then replicates those changes to the corresponding mirror. If WarehousePG detects that a primary segment has failed or become unavailable, it changes the role of its mirror segment to primary segment and the role of the unavailable primary segment to mirror segment. Transactions in progress when the failure occurred roll back and must be restarted. The administrator must then recover the mirror segment, allow the mirror to synchronize with the current primary segment, and then exchange the primary and mirror segments so they are in their preferred roles.

If segment mirroring is not enabled, the WarehousePG cluster shuts down if a segment instance fails. Administrators must manually recover all failed segments before WarehousePG operations can resume.

When segment mirroring is enabled for an existing system, the primary segment instances continue to provide service to users while a snapshot of the primary segments are taken. While the snapshots are taken and deployed on the mirror segment instances, changes to the primary segment are also recorded. After the snapshot has been deployed on the mirror segment, the mirror segment is synchronized and kept current using Write-Ahead Logging (WAL)-based streaming replication. WarehousePG WAL replication uses the `walsender` and `walreceiver` replication processes. The `walsender` process is a primary segment process. The `walreceiver` is a mirror segment process.

When database changes occur, the logs that capture the changes are streamed to the mirror segment to keep it current with the corresponding primary segments. During WAL replication, database changes are written to the logs before being applied, to ensure data integrity for any in-process operations.

When WarehousePG detects a primary segment failure, the WAL replication process stops and the mirror segment automatically starts as the active primary segment. If a mirror segment fails or becomes inaccessible while the primary is active, the primary segment tracks database changes in logs that are applied to the mirror when it is recovered. For information about segment fault detection and the recovery process, see How WarehousePG Detects a Failed Segment and Recovering from Segment Failures.

These WarehousePG cluster catalog tables contain mirroring and replication information.

- The catalog table gp_segment_configuration contains the current configuration and state of primary and mirror segment instances and the coordinator and standby coordinator instance.
- The catalog view gp_stat_replication contains replication statistics of the `walsender` processes that are used for WarehousePG coordinator and segment mirroring.

About Segment Mirroring Configurations

Mirror segment instances can be placed on hosts in the cluster in different configurations. As a best practice, a primary segment and the corresponding mirror are placed on different hosts. Each host must have the same number of primary and mirror segments. When you create segment mirrors with the WarehousePG utilities gpinitsystem or gpaddmirrors you can specify the segment mirror configuration, group mirroring (the default) or spread mirroring. With `gpaddmirrors`, you can create custom mirroring configurations with a `gpaddmirrors` configuration file and specify the file on the command line.

Group mirroring is the default mirroring configuration when you enable mirroring during system initialization. The mirror segments for each host's primary segments are placed on one other host. If a single host fails, the number of active primary segments doubles on the host that backs the failed host. The following figure illustrates a group mirroring configuration.

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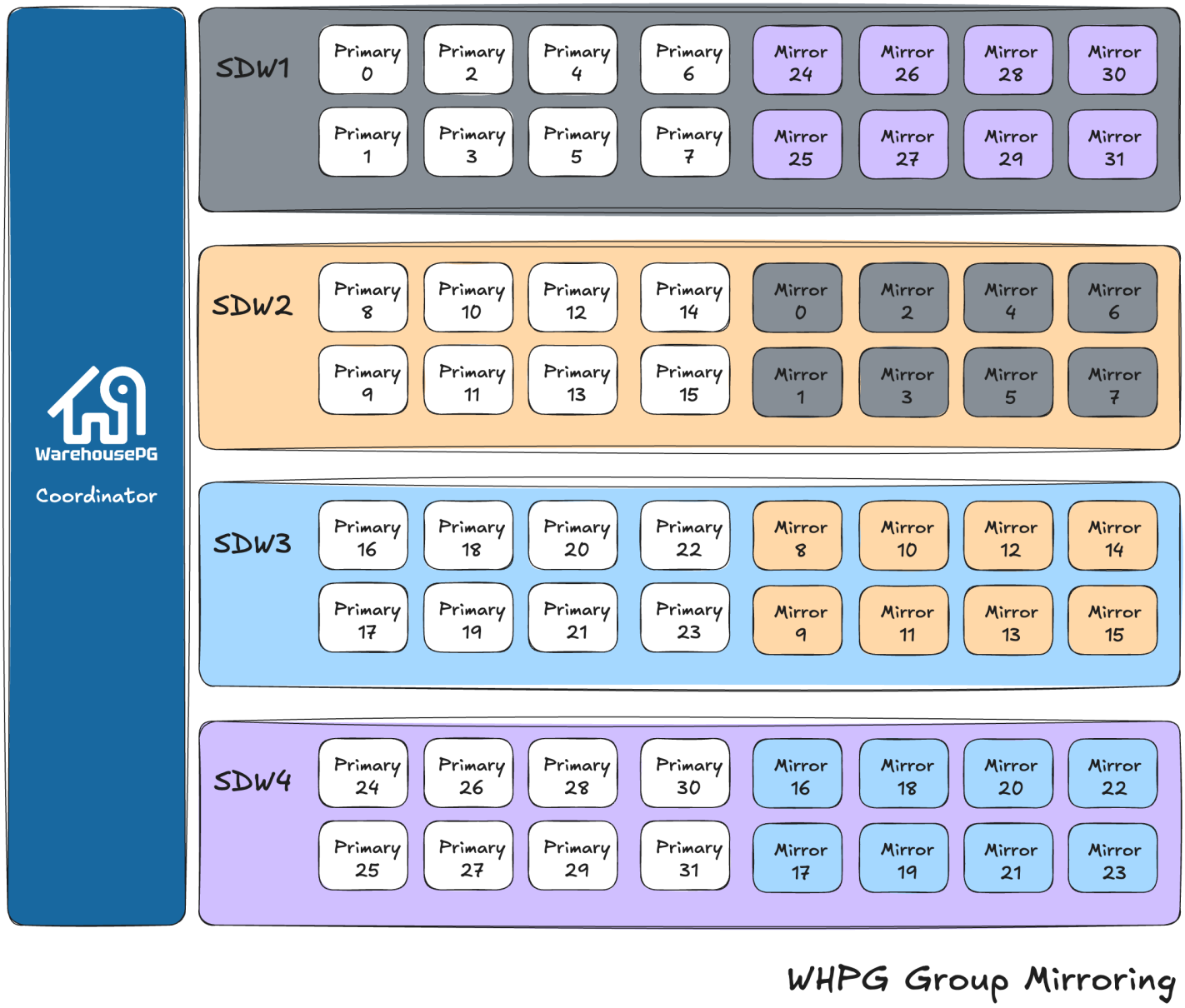

WHPG Group Mirroring

Spread mirroring can be specified during system initialization. This configuration spreads each host's mirrors over multiple hosts so that if any single host fails, no other host will have more than one mirror promoted to an active primary segment. Spread mirroring is possible only if there are more hosts than segments per host. The following figure illustrates the placement of mirrors in a spread segment mirroring configuration.

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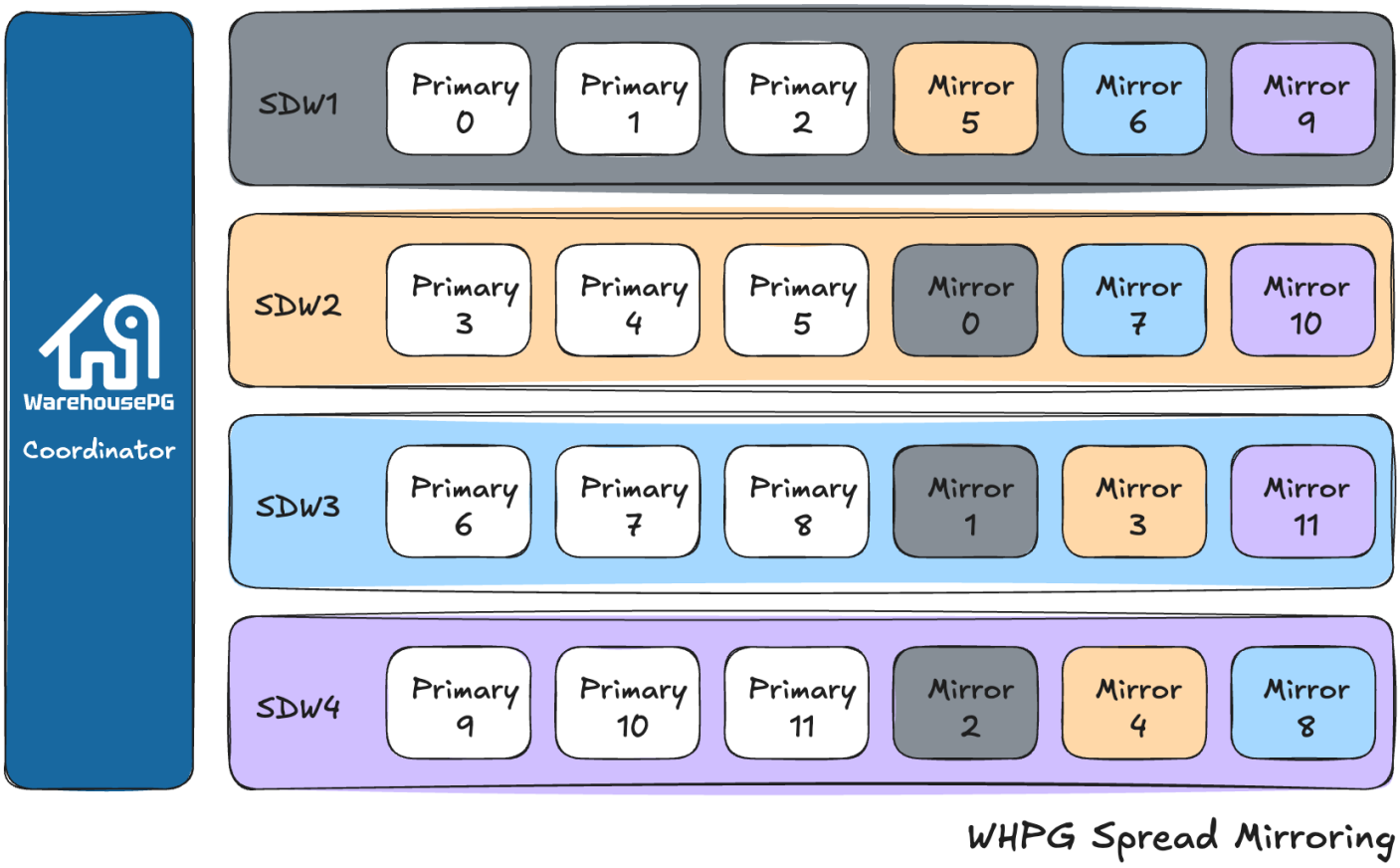

Note You must ensure you have the appropriate number of host systems for your mirroring configuration when you create a system or when you expand a system. For example, to create a system that is configured with spread mirroring requires more hosts than segment instances per host, and a system that is configured with group mirroring requires at least two new hosts when expanding the system. For information about segment mirroring configurations, see Segment Mirroring Configurations. For information about expanding systems with segment mirroring enabled, seePlanning Mirror Segments.

Parent topic: Overview of WarehousePG High Availability

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4.2.7.10 Restoring Coordinator Mirroring After a Recovery

After you activate a standby coordinator for recovery, the standby coordinator becomes the primary coordinator. You can continue running that instance as the primary coordinator if it has the same capabilities and dependability as the original coordinator host.

You must initialize a new standby coordinator to continue providing coordinator mirroring unless you have already done so while activating the prior standby coordinator. Run`gpinitstandby` on the active coordinator host to configure a new standby coordinator. See Enabling Coordinator Mirroring.

You can restore the primary and standby coordinator instances on the original hosts. This process swaps the roles of the primary and standby coordinator hosts, and it should be performed only if you strongly prefer to run the coordinator instances on the same hosts they occupied prior to the recovery scenario.

> **Important** Restoring the primary and standby coordinator instances to their original hosts is not an online operation. The coordinator host must be stopped to perform the operation.

For information about the WarehousePG utilities, see the *WarehousePG Utility Guide*.

Parent topic: Recovering a Failed Coordinator

To restore the coordinator mirroring after a recovery

1. Ensure the original coordinator host is in dependable running condition; ensure the cause of the original failure is fixed.
2. On the original coordinator host, move or remove the data directory, `gpseg-1`. This example moves the directory to `backup_gpseg-1`:

   ```
   $ mv /data/coordinator/gpseg-1 /data/coordinator/backup_gpseg-1
   ```

   You can remove the backup directory once the standby is successfully configured.
3. Initialize a standby coordinator on the original coordinator host. For example, run this command from the current coordinator host, scdw:

   ```
   $ gpinitstandby -s cdw
   ```
4. After the initialization completes, check the status of standby coordinator, cdw. Run`gpstate` with the `-f` option to check the standby coordinator status:

   ```
   $ gpstate -f
   ```

   The standby coordinator status should be `passive`, and the WAL sender state should be `streaming`.

To restore the coordinator and standby instances on original hosts (optional)

> **Note** Before performing the steps in this section, be sure you have followed the steps to restore coordinator mirroring after a recovery, as described in the`To restore the coordinator mirroring after a recovery`previous section.

1. Stop the WarehousePG coordinator instance on the standby coordinator. For example:

   ```
   $ gpstop -m
   ```
2. Run the `gpactivatestandby` utility from the original coordinator host, cdw, that is currently a standby coordinator. For example:

   ```
   $ gpactivatestandby -d $COORDINATOR_DATA_DIRECTORY
   ```

   Where the `-d` option specifies the data directory of the host you are activating.

   > **NOTE** Before running `gpactivatestandby`, be sure to run `gpstate -f` to confirm that the standby coordinator is synchronized with the current coordinator node. If synchronized, the final line of the `gpstate -f` output will look similar to this: `20230607:06:50:06:004205 gpstate:test1-m:gpadmin-[INFO]:--Sync state: sync`
3. After the utility completes, run `gpstate` with the `-b` option to display a summary of the system status:

   ```
   $ gpstate -b
   ```

   The coordinator instance status should be `Active`. When a standby coordinator is not configured, the command displays `No coordinator standby configured` for the standby coordinator state.
4. On the standby coordinator host, move or remove the data directory, `gpseg-1`. This example moves the directory:

   ```
   $ mv /data/coordinator/gpseg-1 /data//backup_gpseg-1
   ```

   You can remove the backup directory once the standby is successfully configured.
5. After the original coordinator host runs the primary WarehousePG coordinator, you can initialize a standby coordinator on the original standby coordinator host. For example:

   ```
   $ gpinitstandby -s scdw
   ```

   After the command completes, you can run the `gpstate -f` command on the primary coordinator host, to check the standby coordinator status.

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To check the status of the coordinator mirroring process (optional)

You can run the `gpstate` utility with the `-f` option to display details of the standby coordinator host.

```
$ gpstate -f
```

The standby coordinator status should be `passive`, and the WAL sender state should be `streaming`.

For information about the gpstate utility, see the *WarehousePG Utility Guide*.

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4.2.8 Backing Up and Restoring Databases

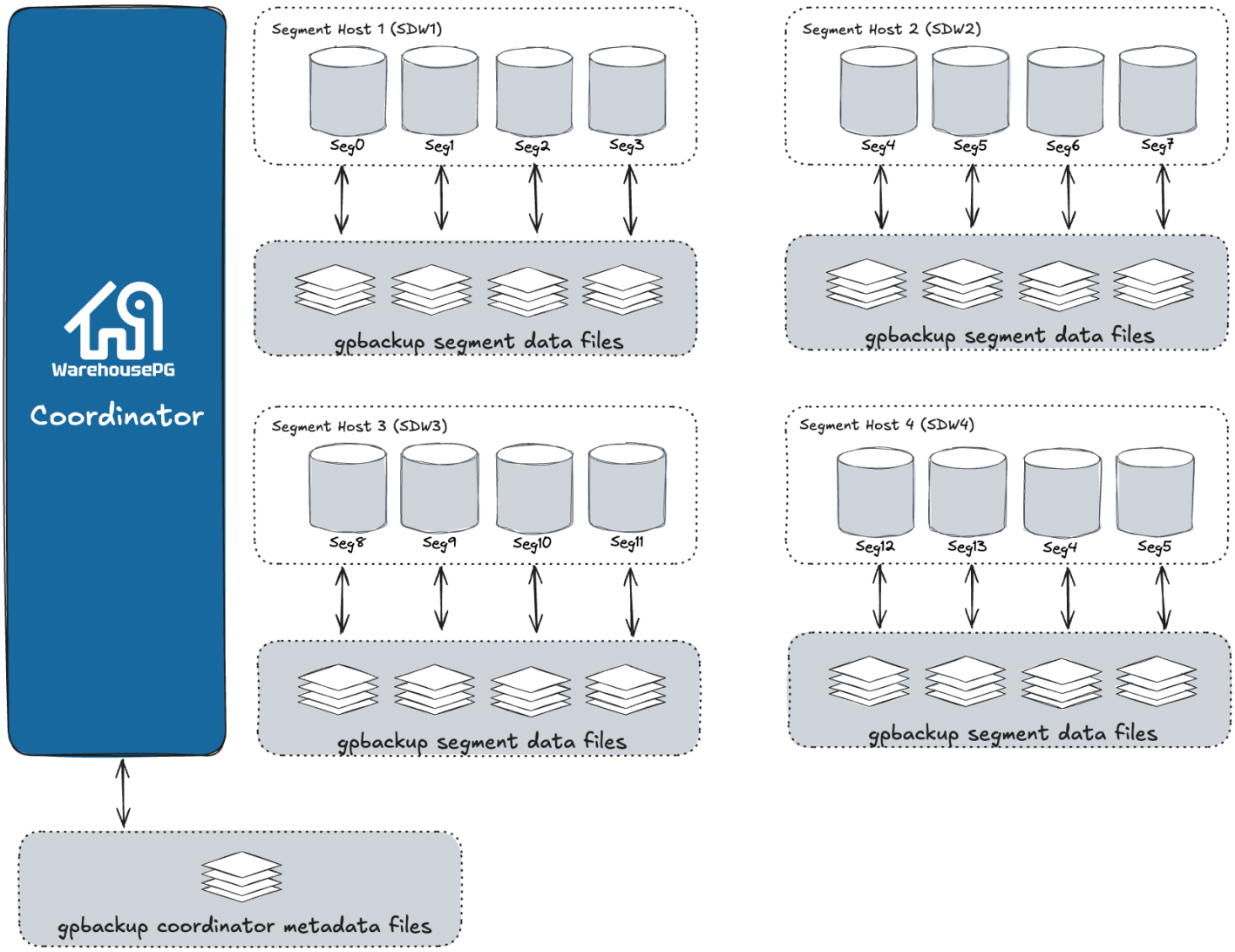
Performing backups regularly ensures that you can restore your data or rebuild your WarehousePG cluster if data corruption or a system failure occurs. You can also use backups to migrate data from one WarehousePG cluster to another.

WarehousePG supports parallel and non-parallel methods for backing up and restoring databases. Parallel operations scale regardless of the number of segments in your system, because segment hosts each write their data to local disk storage simultaneously. With non-parallel backup and restore operations, the data must be sent over the network from the segments to the coordinator, which writes all of the data to its storage. In addition to restricting I/O to one host, non-parallel backup requires that the coordinator have sufficient local disk storage to store the entire database.

Parallel Backup with gpbackup and gprestore

`gpbackup` and `gprestore` are the recommended WarehousePG backup and restore utilities. `gpbackup` utilizes `ACCESS SHARE` locks at the individual table level, instead of `EXCLUSIVE` locks on the `pg_class` catalog table. This enables you to run DML statements during the backup, such as `CREATE`, `ALTER`, `DROP`, and `TRUNCATE` operations, as long as those operations do not target the current backup set. Backup files created with `gpbackup` are designed to provide future capabilities for restoring individual database objects along with their dependencies, such as functions and required user-defined datatypes.

`gpbackup`, `gprestore`, and related utilities are provided as a separate download



Non-Parallel Backup with pg_dump

The PostgreSQL `pg_dump` and `pg_dumpall` non-parallel backup utilities can be used to create a single dump file on the coordinator host that contains all data from all active segments.

The PostgreSQL non-parallel utilities should be used only for special cases. They are much slower than using the WarehousePG backup utilities since all of the data must pass through the coordinator. Additionally, it is often the case that the coordinator host has insufficient disk space to save a backup of an entire distributed WarehousePG.

The `pg_restore` utility requires compressed dump files created by `pg_dump` or `pg_dumpall`. To perform a non-parallel restore using parallel backup files, you can copy the backup files from each segment host to the coordinator host, and then load them through the coordinator.

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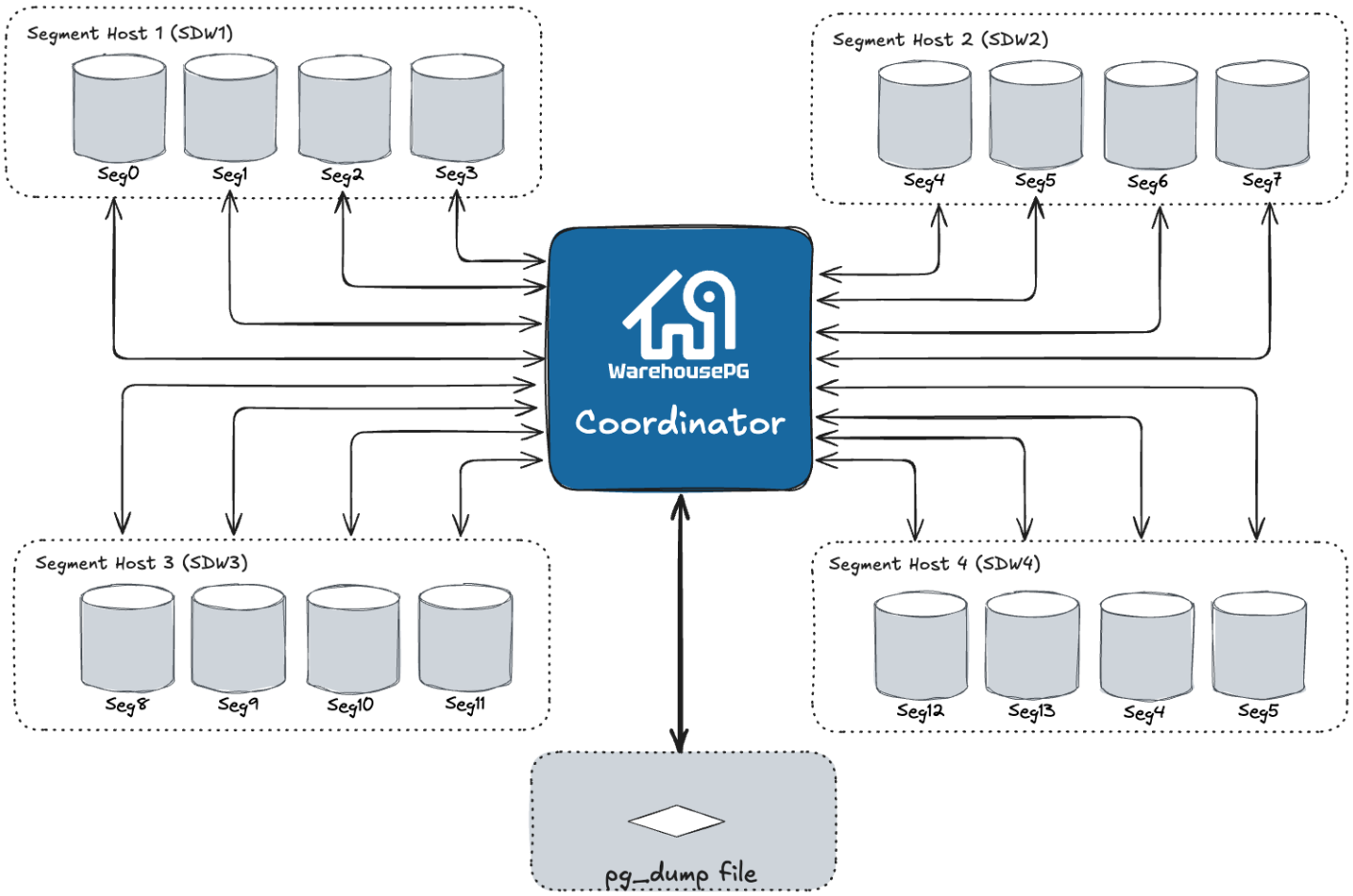

Another non-parallel method for backing up WarehousePG data is to use the `COPY TO` SQL command to copy all or a portion of a table out of the database to a delimited text file on the coordinator host.

Parent topic: Managing a WarehousePG cluster

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4.2.9 Expanding a WarehousePG cluster

To scale up performance and storage capacity, expand your WarehousePG cluster by adding hosts to the system. In general, adding nodes to a WarehousePG cluster achieves a linear scaling of performance and storage capacity.

Data warehouses typically grow over time as additional data is gathered and the retention periods increase for existing data. At times, it is necessary to increase database capacity to consolidate different data warehouses into a single database. Additional computing capacity (CPU) may also be needed to accommodate newly added analytics projects. Although it is wise to provide capacity for growth when a system is initially specified, it is not generally possible to invest in resources long before they are required. Therefore, you should expect to run a database expansion project periodically.

Because of the WarehousePG MPP architecture, when you add resources to the system, the capacity and performance are the same as if the system had been originally implemented with the added resources. Unlike data warehouse systems that require substantial downtime in order to dump and restore the data, expanding a WarehousePG cluster is a phased process with minimal downtime. Regular and ad hoc workloads can continue while data is redistributed and transactional consistency is maintained. The administrator can schedule the distribution activity to fit into ongoing operations and can pause and resume as needed. Tables can be ranked so that datasets are redistributed in a prioritized sequence, either to ensure that critical workloads benefit from the expanded capacity sooner, or to free disk space needed to redistribute very large tables.

The expansion process uses standard WarehousePG operations so it is transparent and easy for administrators to troubleshoot. Segment mirroring and any replication mechanisms in place remain active, so fault-tolerance is uncompromised and disaster recovery measures remain effective.

- **System Expansion Overview**
  You can perform a WarehousePG expansion to add segment instances and segment hosts with minimal downtime. In general, adding nodes to a WarehousePG cluster achieves a linear scaling of performance and storage capacity.
- **Planning WarehousePG cluster Expansion**
  Careful planning will help to ensure a successful WarehousePG expansion project.
- **Preparing and Adding Hosts**
  Verify your new host systems are ready for integration into the existing WarehousePG cluster.
- **Initializing New Segments**
  Use the `gpexpand` utility to create and initialize the new segment instances and create the expansion schema.
- **Redistributing Tables**
  Redistribute tables to balance existing data over the newly expanded cluster.
- **Post Expansion Tasks**
  After the expansion is completed, you must perform different tasks depending on your environment.

Parent topic: Managing a WarehousePG cluster

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4.2.9.1 System Expansion Overview

You can perform a WarehousePG expansion to add segment instances and segment hosts with minimal downtime. In general, adding nodes to a WarehousePG cluster achieves a linear scaling of performance and storage capacity.

Data warehouses typically grow over time, often at a continuous pace, as additional data is gathered and the retention period increases for existing data. At times, it is necessary to increase database capacity to consolidate disparate data warehouses into a single database. The data warehouse may also require additional computing capacity (CPU) to accommodate added analytics projects. It is good to provide capacity for growth when a system is initially specified, but even if you anticipate high rates of growth, it is generally unwise to invest in capacity long before it is required. Database expansion, therefore, is a project that you should expect to have to run periodically.

When you expand your database, you should expect the following qualities:

- Scalable capacity and performance. When you add resources to a WarehousePG, the capacity and performance are the same as if the system had been originally implemented with the added resources.
- Uninterrupted service during expansion, once past the initialization phase. Regular workloads, both scheduled and ad-hoc, are not interrupted.
- Transactional consistency.
- Fault tolerance. During the expansion, standard fault-tolerance mechanisms—such as segment mirroring—remain active, consistent, and effective.
- Replication and disaster recovery. Any existing replication mechanisms continue to function during expansion. Restore mechanisms needed in case of a failure or catastrophic event remain effective.
- Transparency of process. The expansion process employs standard WarehousePG mechanisms, so administrators can diagnose and troubleshoot any problems.
- Configurable process. Expansion can be a long running process, but it can be fit into a schedule of ongoing operations. The expansion schema's tables allow administrators to prioritize the order in which tables are redistributed, and the expansion activity can be paused and resumed.

The planning and physical aspects of an expansion project are a greater share of the work than expanding the database itself. It will take a multi-discipline team to plan and run the project. For on-premise installations, space must be acquired and prepared for the new servers. The servers must be specified, acquired, installed, cabled, configured, and tested. For cloud deployments, similar plans should also be made. Planning New Hardware Platforms describes general considerations for deploying new hardware.

After you provision the new hardware platforms and set up their networks, configure the operating systems and run performance tests using WarehousePG utilities. The WarehousePG software distribution includes utilities that are helpful to test and burn-in the new servers before beginning the software phase of the expansion. See Preparing and Adding Hosts for steps to prepare the new hosts for WarehousePG.

Once the new servers are installed and tested, the software phase of the WarehousePG expansion process begins. The software phase is designed to be minimally disruptive, transactionally consistent, reliable, and flexible.

- The first step of the software phase of expansion process is preparing the WarehousePG cluster: adding new segment hosts and initializing new segment instances. This phase can be scheduled to occur during a period of low activity to avoid disrupting ongoing business operations. During the initialization process, the following tasks are performed:
    - WarehousePG software is installed.
    - Databases and database objects are created in the new segment instances on the new segment hosts.
    - The *gpexpand* schema is created in the postgres database. You can use the tables and view in the schema to monitor and control the expansion process. After the system has been updated, the new segment instances on the new segment hosts are available.
    - New segments are immediately available and participate in new queries and data loads. The existing data, however, is skewed. It is concentrated on the original segments and must be redistributed across the new total number of primary segments.
    - Because some of the table data is skewed, some queries might be less efficient because more data motion operations might be needed.
- The last step of the software phase is redistributing table data. Using the expansion control tables in the*gpexpand* schema as a guide, tables are redistributed. For each table:
    - The gpexand utility redistributes the table data, across all of the servers, old and new, according to the distribution policy.
    - The table's status is updated in the expansion control tables.
    - After data redistribution, the query optimizer creates more efficient execution plans when data is not skewed. When all tables have been redistributed, the expansion is complete.

> **Important** The `gprestore` utility cannot restore backups you made before the expansion with the `gpbackup` utility, so back up your databases immediately after the system expansion is complete.

Redistributing table data is a long-running process that creates a large volume of network and disk activity. It can take days to redistribute some very large databases. To minimize the effects of the increased activity on business operations, system administrators can pause and resume expansion activity on an ad hoc basis, or according to a predetermined schedule. Datasets can be prioritized so that critical applications benefit first from the expansion.

In a typical operation, you run the `gpexpand` utility four times with different options during the complete expansion process.

1. To create an expansion input file:

    ```
    gpexpand -f <hosts_file>
    ```

2. To initialize segments and create the expansion schema:

    ```
    gpexpand -i <input_file>
    ```

    `gpexpand` creates a data directory, copies user tables from all existing databases on the new segments, and captures metadata for each table in an expansion schema for status tracking. After this process completes, the expansion operation is committed and irrevocable.

3. To redistribute table data:

    ```
    gpexpand -d <duration>
    ```

    During initialization, `gpexpand` adds and initializes new segment instances. To complete system expansion, you must run `gpexpand` to redistribute data tables across the newly added segment instances. Depending on the size and scale of your system, redistribution can be accomplished in a single session during low-use hours, or you can divide the process into batches over an extended period. Each table or partition is unavailable for read or write operations during redistribution. As each table is redistributed across the new segments, database performance should incrementally improve until it exceeds pre-expansion performance levels.

    You may need to run `gpexpand` several times to complete the expansion in large-scale systems that require multiple redistribution sessions. `gpexpand` can benefit from explicit table redistribution ranking; see Planning Table Redistribution.

    Users can access WarehousePG during initialization, but they may experience performance degradation on systems that rely heavily on hash distribution of tables. Normal operations such as ETL jobs, user queries, and reporting can continue, though users might experience slower response times.

4. To remove the expansion schema:

    ```
    gpexpand -c
    ```

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For information about the gpexpand utility and the other utilities that are used for system expansion, see the *WarehousePG Utility Guide*.

Parent topic: Expanding a WarehousePG cluster

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4.2.9.2 Planning WarehousePG cluster Expansion

Careful planning will help to ensure a successful WarehousePG expansion project.

The topics in this section help to ensure that you are prepared to perform a system expansion.

- System Expansion Checklist is a checklist you can use to prepare for and perform the system expansion process.
- Planning New Hardware Platforms covers planning for acquiring and setting up the new hardware.
- Planning New Segment Initialization provides information about planning to initialize new segment hosts with `gpexpand`.
- Planning Table Redistribution provides information about planning the data redistribution after the new segment hosts have been initialized.

> **Important** When expanding a WarehousePG cluster, you must deactivate WarehousePG interconnect proxies before adding new hosts and segment instances to the system, and you must update the `gp_interconnect_proxy_addresses` parameter with the newly-added segment instances before you re-enable interconnect proxies. For example, these commands deactivate WarehousePG interconnect proxies by setting the interconnect to the default (`UDPIFC`) and reloading the `postgresql.conf` file to update the WarehousePG cluster configuration.

```
gpconfig -r gp_interconnect_type
gpstop -u
```

For information about WarehousePG interconnect proxies, see Configuring Proxies for the WarehousePG Interconnect.

Parent topic: Expanding a WarehousePG cluster

System Expansion Checklist

This checklist summarizes the tasks for a WarehousePG cluster expansion.

Online Pre-Expansion Tasks

System status: Up and available

- [ ] **Hardware Provisioning:** Plan for ordering, building, and networking new hardware platforms, or provisioning cloud resources.
- [ ] **Expansion Planning:** Devise a database expansion plan. Map the number of segments per host, schedule downtime for performance testing and schema creation, and set intervals for table redistribution.
- [ ] **Schema Backup:** Perform a complete schema dump.
- [ ] **Binary Installation:** Install WarehousePG binaries on new hosts.
- [ ] **SSH Configuration:** Copy SSH keys to the new hosts (`gpssh-exkeys`).
- [ ] **Hardware Validation:** Validate disk I/O and memory bandwidth of the new hardware or cloud resources (`gpcheckperf`).
- [ ] **Log Maintenance:** Validate that the coordinator data directory has no extremely large files in the `log` directory.

Offline Pre-Expansion Tasks

System status: Unavailable to all user activity during this process

- [ ] **Catalog Validation:** Validate that there are no catalog issues (`gpcheckcat`).
- [ ] **Full Cluster Validation:** Validate disk I/O and memory bandwidth of the combined existing and new hardware or cloud resources (`gpcheckperf`).

Online Segment Instance Initialization

System status: Up and available

- [ ] **Input File Preparation:** Prepare an expansion input file (`gpexpand`).
- [ ] **Initialization:** Initialize new segments into the system and create an expansion schema (`gpexpand -i input_file`).

Online Expansion and Table Redistribution

System status: Up and available

- [ ] **Resource Cleanup:** Before you start table redistribution, stop any automated snapshot processes or other processes that consume disk space.
- [ ] **Redistribution:** Redistribute tables through the expanded system (`gpexpand`).
- [ ] **Cleanup:** Remove expansion schema (`gpexpand -c`).
- [ ] **Statistics Update: Important:** Run `analyze` to update distribution statistics. During the expansion, use `gpexpand -a`, and post-expansion, use `analyze`.

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Back Up Databases

System status: Up and available

- [ ] **Fresh Backup:** Back up databases using the `gpbackup` utility.

> **Note**
>
> Backups created before the system expansion cannot be restored to the newly expanded system because the `gprestore` utility can only restore backups to a WarehousePG cluster with the same number of segments.

Planning New Hardware Platforms

A deliberate, thorough approach to deploying compatible hardware greatly minimizes risk to the expansion process.

Hardware resources and configurations for new segment hosts should match those of the existing hosts.

The steps to plan and set up new hardware platforms vary for each deployment. Some considerations include how to:

- Prepare the physical space for the new hardware; consider cooling, power supply, and other physical factors.
- Determine the physical networking and cabling required to connect the new and existing hardware.
- Map the existing IP address spaces and developing a networking plan for the expanded system.
- Capture the system configuration (users, profiles, NICs, and so on) from existing hardware to use as a detailed list for ordering new hardware.
- Create a custom build plan for deploying hardware with the desired configuration in the particular site and environment.

After selecting and adding new hardware to your network environment, ensure you perform the tasks described inPreparing and Adding Hosts.

Planning New Segment Initialization

Expanding WarehousePG can be performed when the system is up and available. Run `gpexpand` to initialize new segment instances into the system and create an expansion schema.

The time required depends on the number of schema objects in the WarehousePG cluster and other factors related to hardware performance. In most environments, the initialization of new segments requires less than thirty minutes offline.

These utilities cannot be run while `gpexpand` is performing segment initialization.

- `gpbackup`
- `gpcheckcat`
- `gpconfig`
- `gprestore`

> **Important** After you begin initializing new segments, you can no longer restore the system using backup files created for the pre-expansion system. When initialization successfully completes, the expansion is committed and cannot be rolled back.

Planning Mirror Segments

If your existing system has mirror segments, the new segments must have mirroring configured. If there are no mirrors configured for existing segments, you cannot add mirrors to new hosts with the `gpexpand` utility. For more information about segment mirroring configurations that are available during system initialization, see About Segment Mirroring Configurations.

For WarehousePG clusters with mirror segments, ensure you add enough new host machines to accommodate new mirror segments. The number of new hosts required depends on your mirroring strategy:

- **Group Mirroring** — Add at least two new hosts so the mirrors for the first host can reside on the second host, and the mirrors for the second host can reside on the first. This is the default type of mirroring if you enable segment mirroring during system initialization.
- **Spread Mirroring** — Add at least one more host to the system than the number of segments per host. The number of separate hosts must be greater than the number of segment instances per host to ensure even spreading. You can specify this type of mirroring during system initialization or when you enable segment mirroring for an existing system.
- **Block Mirroring** — Adding one or more blocks of host systems. For example add a block of four or eight hosts. Block mirroring is a custom mirroring configuration. For more information about block mirroring, seeSegment Mirroring Configurations.

Increasing Segments Per Host

By default, new hosts are initialized with as many primary segments as existing hosts have. You can increase the segments per host or add new segments to existing hosts.

For example, if existing hosts currently have two segments per host, you can use `gpexpand` to initialize two additional segments on existing hosts for a total of four segments and initialize four new segments on new hosts.

The interactive process for creating an expansion input file prompts for this option; you can also specify new segment directories manually in the input configuration file. For more information, seeCreating an Input File for System Expansion.

About the Expansion Schema

At initialization, the `gpexpand` utility creates an expansion schema named *gpexpand* in the postgres database.

The expansion schema stores metadata for each table in the system so its status can be tracked throughout the expansion process. The expansion schema consists of two tables and a view for tracking expansion operation progress:

- *gpexpand.status*
- *gpexpand.status_detail*
- *gpexpand.expansion_progress*

Control expansion process aspects by modifying *gpexpand.status_detail*. For example, removing a record from this table prevents the system from expanding the table across new segments. Control the order in which tables are processed for redistribution by updating the `rank` value for a record. For more information, see Ranking Tables for Redistribution.

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Planning Table Redistribution

Table redistribution is performed while the system is online. For many WarehousePG clusters, table redistribution completes in a single `gpexpand` session scheduled during a low-use period. Larger systems may require multiple sessions and setting the order of table redistribution to minimize performance impact. Complete the table redistribution in one session if possible.

> **Important** To perform table redistribution, your segment hosts must have enough disk space to temporarily hold a copy of your largest table. All tables are unavailable for read and write operations during redistribution.

The performance impact of table redistribution depends on the size, storage type, and partitioning design of a table. For any given table, redistributing it with `gpexpand` takes as much time as a `CREATE TABLE AS SELECT` operation would. When redistributing a terabyte-scale fact table, the expansion utility can use much of the available system resources, which could affect query performance or other database workloads.

Table Redistribution Method

WarehousePG uses a *rebuild* table distribution method to redistribute data during an expansion. WarehousePG:

1. Creates a new table.
2. Copies all of the data from the old table to the new table.
3. Replaces the old table.

The rebuild method is similar to creating a new table with a `CREATE TABLE AS SELECT` command. During data redistribution, WarehousePG acquires an `ACCESS EXCLUSIVE` lock on the table.

Managing Redistribution in Large-Scale WarehousePG clusters

When planning the redistribution phase, consider the impact of the `ACCESS EXCLUSIVE` lock taken on each table. User activity on a table can delay its redistribution, but also tables are unavailable for user activity during redistribution.

You can manage the order in which tables are redistributed by adjusting their ranking. SeeRanking Tables for Redistribution. Manipulating the redistribution order can help adjust for limited disk space and restore optimal query performance for high-priority queries sooner.

Systems with Abundant Free Disk Space

In systems with abundant free disk space (required to store a copy of the largest table), you can focus on restoring optimum query performance as soon as possible by first redistributing important tables that queries use heavily. Assign high ranking to these tables, and schedule redistribution operations for times of low system usage. Run one redistribution process at a time until large or critical tables have been redistributed.

Systems with Limited Free Disk Space

If your existing hosts have limited disk space, you may prefer to first redistribute smaller tables (such as dimension tables) to clear space to store a copy of the largest table. Available disk space on the original segments increases as each table is redistributed across the expanded system. When enough free space exists on all segments to store a copy of the largest table, you can redistribute large or critical tables. Redistribution of large tables requires exclusive locks; schedule this procedure for off-peak hours.

Also consider the following:

- Run multiple parallel redistribution processes during off-peak hours to maximize available system resources.
- When running multiple processes, operate within the connection limits for your WarehousePG cluster. For information about limiting concurrent connections, seeLimiting Concurrent Connections.

Redistributing Append-Optimized and Compressed Tables

`gpexpand` redistributes append-optimized and compressed append-optimized tables at different rates than heap tables. The CPU capacity required to compress and decompress data tends to increase the impact on system performance. For similar-sized tables with similar data, you may find overall performance differences like the following:

- Uncompressed append-optimized tables expand 10% faster than heap tables.
- Append-optimized tables that are defined to use data compression expand at a significantly slower rate than uncompressed append-optimized tables, potentially up to 80% slower.
- Systems with data compression such as ZFS/LZJB take longer to redistribute.

> **Important** If your system hosts use data compression, use identical compression settings on the new hosts to avoid disk space shortage.

Redistributing Partitioned Tables

Because the expansion utility can process each individual partition on a large table, an efficient partition design reduces the performance impact of table redistribution. Only the child tables of a partitioned table are set to a random distribution policy. The read/write lock for redistribution applies to only one child table at a time.

Redistributing Indexed Tables

Because the `gpexpand` utility must re-index each indexed table after redistribution, a high level of indexing has a large performance impact. Systems with intensive indexing have significantly slower rates of table redistribution.

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4.2.9.3 Preparing and Adding Hosts

Verify your new host systems are ready for integration into the existing WarehousePG cluster.

To prepare new host systems for expansion, install the WarehousePG software binaries, exchange the required SSH keys, and run performance tests.

Run performance tests first on the new hosts and then all hosts. Run the tests on all hosts with the system offline so user activity does not distort results.

Generally, you should run performance tests when an administrator modifies host networking or other special conditions in the system. For example, if you will run the expanded system on two network clusters, run tests on each cluster.

> **Note** Preparing host systems for use by a WarehousePG cluster assumes that the new hosts' operating system has been properly configured to match the existing hosts, described in Configure Operating System.

Parent topic: Expanding a WarehousePG cluster

Adding New Hosts to the Trusted Host Environment

New hosts must exchange SSH keys with the existing hosts to enable WarehousePG administrative utilities to connect to all segments without a password prompt. Perform the key exchange process twice with the gpssh-exkeys utility.

First perform the process as `root`, for administration convenience, and then as the user `gpadmin`, for management utilities. Perform the following tasks in order:

1. To exchange SSH keys as root
2. To create the gpadmin user
3. To exchange SSH keys as the gpadmin user

> **Note** The WarehousePG segment host naming convention is `sdwN` where `sdw` is a prefix and `N` is an integer (`sdw1`, `sdw2` and so on). For hosts with multiple interfaces, the convention is to append a dash (`-`) and number to the host name. For example, `sdw1-1` and `sdw1-2` are the two interface names for host `sdw1`.

To exchange SSH keys as root

1. Create a host file with the existing host names in your array and a separate host file with the new expansion host names. For existing hosts, you can use the same host file used to set up SSH keys in the system. In the files, list all hosts (coordinator, backup coordinator, and segment hosts) with one name per line and no extra lines or spaces. Exchange SSH keys using the configured host names for a given host if you use a multi-NIC configuration. In this example, `cdw` is configured with a single NIC, and `sdw1`, `sdw2`, and `sdw3` are configured with 4 NICs:

```
cdw
sdw1-1
sdw1-2
sdw1-3
sdw1-4
sdw2-1
sdw2-2
sdw2-3
sdw2-4
sdw3-1
sdw3-2
sdw3-3
sdw3-4
```

2. Log in as `root` on the coordinator host, and source the `greenplum_path.sh` file from your WarehousePG installation.

```
$ su -
# source /usr/edb/whpg7/greenplum_path.sh
```

3. Run the `gpssh-exkeys` utility referencing the host list files. For example:

```
# gpssh-exkeys -e /home/gpadmin/<existing_hosts_file> -x
/home/gpadmin/<new_hosts_file>
```

4. `gpssh-exkeys` checks the remote hosts and performs the key exchange between all hosts. Enter the `root` user password when prompted. For example:

```
***Enter password for root@<hostname>: <root_password>
```

To create the gpadmin user

1. Use gpssh to create the `gpadmin` user on all the new segment hosts (if it does not exist already). Use the list of new hosts you created for the key exchange. For example:

```
# gpssh -f <new_hosts_file> '/usr/sbin/useradd gpadmin -d
/home/gpadmin -s /bin/bash'
```

2. Set a password for the new `gpadmin` user. On Linux, you can do this on all segment hosts simultaneously using `gpssh`. For example:

```
# gpssh -f <new_hosts_file> 'echo <gpadmin_password> | passwd
gpadmin --stdin'
```

3. Verify the `gpadmin` user has been created by looking for its home directory:

```
# gpssh -f <new_hosts_file> ls -l /home
```

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To exchange SSH keys as the gpadmin user

1. Log in as `gpadmin` and run the `gpssh-exkeys` utility referencing the host list files. For example:

   ```
   # gpssh-exkeys -e /home/gpadmin/<existing_hosts_file> -x
   /home/gpadmin/<new_hosts_file>
   ```

2. `gpssh-exkeys` will check the remote hosts and perform the key exchange between all hosts. Enter the `gpadmin` user password when prompted. For example:

   ```
   ***Enter password for gpadmin@<hostname>: <gpadmin_password>
   ```

Validating Disk I/O and Memory Bandwidth

Use the gpcheckperf utility to test disk I/O and memory bandwidth.

To run gpcheckperf

1. Run the `gpcheckperf` utility using the host file for new hosts. Use the `-d` option to specify the file systems you want to test on each host. You must have write access to these directories. For example:

   ```
   $ gpcheckperf -f <new_hosts_file> -d /data1 -d /data2 -v
   ```

2. The utility may take a long time to perform the tests because it is copying very large files between the hosts. When it is finished, you will see the summary results for the Disk Write, Disk Read, and Stream tests.

For a network divided into subnets, repeat this procedure with a separate host file for each subnet.

Integrating New Hardware into the System

Before initializing the system with the new segments, shut down the system with `gpstop` to prevent user activity from skewing performance test results. Then, repeat the performance tests using host files that include *all* hosts, existing and new.

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4.2.9.4 Initializing New Segments

Use the `gpexpand` utility to create and initialize the new segment instances and create the expansion schema.

The first time you run gpexpand with a valid input file it creates and initializes segment instances and creates the expansion schema. After these steps are completed, running `gpexpand` detects if the expansion schema has been created and, if so, performs table redistribution.

> **Note** To prevent catalog inconsistency across existing and new segments, be sure that no DDL operations are running during the initialization phase.

- Creating an Input File for System Expansion
- Running gpexpand to Initialize New Segments
- Rolling Back a Failed Expansion Setup

Parent topic: Expanding a WarehousePG cluster

Creating an Input File for System Expansion

To begin expansion, `gpexpand` requires an input file containing information about the new segments and hosts. If you run `gpexpand` without specifying an input file, the utility displays an interactive interview that collects the required information and automatically creates an input file.

If you create the input file using the interactive interview, you may specify a file with a list of expansion hosts in the interview prompt. If your platform or command shell limits the length of the host list, specifying the hosts with `-f` may be mandatory.

Creating an input file in Interactive Mode

Before you run `gpexpand` to create an input file in interactive mode, ensure you know:

- The number of new hosts (or a hosts file)
- The new hostnames (or a hosts file)
- The mirroring strategy used in existing hosts, if any
- The number of segments to add per host, if any

The utility automatically generates an input file based on this information, `dbid`, `content` ID, and data directory values stored in *gp_segment_configuration*, and saves the file in the current directory.

To create an input file in interactive mode

1. Log in on the coordinator host as the user who will run your WarehousePG cluster; for example, `gpadmin`.
2. Run `gpexpand`. The utility displays messages about how to prepare for an expansion operation, and it prompts you to quit or continue.

   Optionally, specify a hosts file using `-f`. For example:

   ```
   $ gpexpand -f /home/gpadmin/<new_hosts_file>
   ```

3. At the prompt, select `Y` to continue.
4. Unless you specified a hosts file using `-f`, you are prompted to enter hostnames. Enter a comma separated list of the hostnames of the new expansion hosts. Do not include interface hostnames. For example:

   ```
   > sdw4, sdw5, sdw6, sdw7
   ```

   To add segments to existing hosts only, enter a blank line at this prompt. Do not specify `localhost` or any existing host name.
5. Enter the mirroring strategy used in your system, if any. Options are `spread|grouped|none`. The default setting is `grouped`.

   Ensure you have enough hosts for the selected grouping strategy. For more information about mirroring, see Planning Mirror Segments.
6. Enter the number of new primary segments to add, if any. By default, new hosts are initialized with the same number of primary segments as existing hosts. Increase segments per host by entering a number greater than zero. The number you enter will be the number of additional segments initialized on all hosts. For example, if existing hosts currently have two segments each, entering a value of `2` initializes two more segments on existing hosts, and four segments on new hosts.
7. If you are adding new primary segments, enter the new primary data directory root for the new segments. Do not specify the actual data directory name, which is created automatically by `gpexpand` based on the existing data directory names.

   For example, if your existing data directories are as follows:

   ```
   /gpdata/primary/gp0
   /gpdata/primary/gp1
   ```

   then enter the following (one at each prompt) to specify the data directories for two new primary segments:

   ```
   /gpdata/primary
   /gpdata/primary
   ```

   When the initialization runs, the utility creates the new directories `gp2` and `gp3` under `/gpdata/primary`.

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8. If you are adding new mirror segments, enter the new mirror data directory root for the new segments. Do not specify the data directory name; it is created automatically by `gpexpand` based on the existing data directory names.

   For example, if your existing data directories are as follows:

   ```
   /gpdata/mirror/gp0
   /gpdata/mirror/gp1
   ```

   enter the following (one at each prompt) to specify the data directories for two new mirror segments:

   ```
   /gpdata/mirror
   /gpdata/mirror
   ```

   When the initialization runs, the utility will create the new directories `gp2` and `gp3` under `/gpdata/mirror`.

   These primary and mirror root directories for new segments must exist on the hosts, and the user running `gpexpand` must have permissions to create directories in them.

   After you have entered all required information, the utility generates an input file and saves it in the current directory. For example:

   ```
   gpexpand_inputfile_yyyymmdd_145134
   ```

   If the WarehousePG cluster is configured with tablespaces, the utility automatically generates an additional tablespace mapping file. This file is required for later parsing by the utility so make sure it is present before proceeding with the next step. For example:

   ```
   gpexpand_inputfile_yyyymmdd_145134.ts
   ```

Expansion Input File Format

Use the interactive interview process to create your own input file unless your expansion scenario has atypical needs.

The format for expansion input files is:

```
hostname|address|port|datadir|dbid|content|preferred_role
```

For example:

```
sdw5|sdw5-1|50011|/gpdata/primary/gp9|11|9|p
sdw5|sdw5-2|50012|/gpdata/primary/gp10|12|10|p
sdw5|sdw5-2|60011|/gpdata/mirror/gp9|13|9|m
sdw5|sdw5-1|60012|/gpdata/mirror/gp10|14|10|m
```

For each new segment, this format of expansion input file requires the following:

Parameter	Valid Values	Description
hostname	Hostname	Hostname for the segment host.
port	An available port number	Database listener port for the segment, incremented on the existing segment *port* base number.
datadir	Directory name	The data directory location for a segment as per the gp_segment_configuration system catalog.
dbid	Integer. Must not conflict with existing *dbid* values.	Database ID for the segment. The values you enter should be incremented sequentially from existing *dbid* values shown in the system catalog `gp_segment_configuration`. For example, to add four segment instances to an existing ten-segment array with *dbid* values of 1-10, list new *dbid* values of 11, 12, 13 and 14.
content	Integer. Must not conflict with existing *content* values.	The content ID of the segment. A primary segment and its mirror should have the same content ID, incremented sequentially from existing values. For more information, see *content* in the reference for `gp_segment_configuration`.
preferred_role	`p` or `m`	Determines whether this segment is a primary or mirror. Specify `p` for primary and `m` for mirror.

Running gpexpand to Initialize New Segments

After you have created an input file, run `gpexpand` to initialize new segment instances.

To run gpexpand with an input file

1. Log in on the coordinator host as the user who will run your WarehousePG cluster; for example, `gpadmin`.
2. Run the `gpexpand` utility, specifying the input file with `-i`. For example:

   ```
   $ gpexpand -i input_file
   ```

   The utility detects if an expansion schema exists for the WarehousePG cluster. If a *gpexpand* schema exists, remove it with `gpexpand -c` before you start a new expansion operation. See Removing the Expansion Schema.

   When the new segments are initialized and the expansion schema is created, the utility prints a success message and exits.

When the initialization process completes, you can connect to WarehousePG and view the expansion schema. The *gpexpand* schema resides in the postgres database. For more information, see About the Expansion Schema.

After segment initialization is complete, redistribute the tables to balance existing data over the new segments.

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Monitoring the Cluster Expansion State

At any time, you can check the state of cluster expansion by running the `gpstate` utility with the `-x` flag:

```
$ gpstate -x
```

If the expansion schema exists in the postgres database, `gpstate -x` reports on the progress of the expansion. During the first expansion phase, `gpstate` reports on the progress of new segment initialization. During the second phase, `gpstate` reports on the progress of table redistribution, and whether redistribution is paused or active.

You can also query the expansion schema to see expansion status. See Monitoring Table Redistribution for more information.

Rolling Back a Failed Expansion Setup

You can roll back an expansion setup operation (adding segment instances and segment hosts) only if the operation fails.

If the expansion fails during the initialization step, while the database is down, you must first restart the database in coordinator-only mode by running the `gpstart -m` command.

Roll back the failed expansion with the following command:

```
gpexpand --rollback
```

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4.2.9.5 Redistributing Tables

Redistribute tables to balance existing data over the newly expanded cluster.

After creating an expansion schema, you can redistribute tables across the entire system with gpexpand. Plan to run this during low-use hours when the utility's CPU usage and table locks have minimal impact on operations. Rank tables to redistribute the largest or most critical tables first.

> **Note** When redistributing data, WarehousePG must be running in production mode. WarehousePG cannot be in restricted mode or in coordinator mode. The gpstart options `-R` or `-m` cannot be specified to start WarehousePG.

While table redistribution is underway, any new tables or partitions created are distributed across all segments exactly as they would be under normal operating conditions. Queries can access all segments, even before the relevant data is redistributed to tables on the new segments. The table or partition being redistributed is locked and unavailable for read or write operations. When its redistribution completes, normal operations resume.

- Ranking Tables for Redistribution
- Redistributing Tables Using gpexpand
- Monitoring Table Redistribution

Parent topic: Expanding a WarehousePG cluster

Ranking Tables for Redistribution

For large systems, you can control the table redistribution order. Adjust tables' `rank` values in the expansion schema to prioritize heavily-used tables and minimize performance impact. Available free disk space can affect table ranking; see Managing Redistribution in Large-Scale WarehousePG clusters.

To rank tables for redistribution by updating `rank` values in *gpexpand.status_detail*, connect to WarehousePG using `psql` or another supported client. Update *gpexpand.status_detail* with commands such as:

```
=> UPDATE gpexpand.status_detail SET rank=10;

=> UPDATE gpexpand.status_detail SET rank=1 WHERE fq_name = 'public.lineitem';
=> UPDATE gpexpand.status_detail SET rank=2 WHERE fq_name = 'public.orders';
```

These commands lower the priority of all tables to `10` and then assign a rank of `1` to `lineitem` and a rank of `2` to `orders`. When table redistribution begins, `lineitem` is redistributed first, followed by `orders` and all other tables in *gpexpand.status_detail*. To exclude a table from redistribution, remove the table from the *gpexpand.status_detail* table.

Redistributing Tables Using gpexpand

To redistribute tables with gpexpand

1. Log in on the coordinator host as the user who will run your WarehousePG cluster, for example, `gpadmin`.
2. Run the `gpexpand` utility. You can use the `-d` or `-e` option to define the expansion session time period. For example, to run the utility for up to 60 consecutive hours:

   ```
   $ gpexpand -d 60:00:00
   ```

   The utility redistributes tables until the last table in the schema completes or it reaches the specified duration or end time. `gpexpand` updates the status and time in *gpexpand.status* when a session starts and finishes.

> **Note** After completing table redistribution, run the `VACUUM ANALYZE` and `REINDEX` commands on the catalog tables to update table statistics, and rebuild indexes. See Routine Vacuum and Analyze in the *Administration Guide* and `VACUUM` in the *Reference Guide*.

Monitoring Table Redistribution

During the table redistribution process you can query the expansion schema to view:

- a current progress summary, the estimated rate of table redistribution, and the estimated time to completion. Use *gpexpand.expansion_progress*, as described in Viewing Expansion Status.
- per-table status information, using *gpexpand.status_detail*. See Viewing Table Status.

See also Monitoring the Cluster Expansion State for information about monitoring the overall expansion progress with the `gpstate` utility.

Viewing Expansion Status

After the first table completes redistribution, *gpexpand.expansion_progress* calculates its estimates and refreshes them based on all tables' redistribution rates. Calculations restart each time you start a table redistribution session with `gpexpand`. To monitor progress, connect to WarehousePG using `psql` or another supported client; query *gpexpand.expansion_progress* with a command like the following:

```
=# SELECT * FROM gpexpand.expansion_progress;
             name             |         value
------------------------------+-----------------------
 Bytes Left                   | 5534842880
 Bytes Done                   | 142475264
 Estimated Expansion Rate     | 680.75667095996092 MB/s
 Estimated Time to Completion | 00:01:01.008047
 Tables Expanded              | 4
 Tables Left                  | 4
(6 rows)
```

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Viewing Table Status

The table *gpexpand.status_detail* stores status, time of last update, and more facts about each table in the schema. To see a table's status, connect to WarehousePG using `psql` or another supported client and query *gpexpand.status_detail*:

```
=> SELECT status, expansion_started, source_bytes FROM
gpexpand.status_detail WHERE fq_name = 'public.sales';
  status   |     expansion_started      | source_bytes
-----------+----------------------------+--------------
 COMPLETED | 2017-02-20 10:54:10.043869 |   4929748992
(1 row)
```

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4.2.9.6 Post Expansion Tasks

After the expansion is completed, you must perform different tasks depending on your environment.

- Removing the Expansion Schema
- Setting Up PXF on the New Host

Parent topic: Expanding a WarehousePG cluster

Removing the Expansion Schema

You must remove the existing expansion schema before you can perform another expansion operation on the WarehousePG cluster.

You can safely remove the expansion schema after the expansion operation is complete and verified. To run another expansion operation on a WarehousePG cluster, first remove the existing expansion schema.

1. Log in on the coordinator host as the user who will be running your WarehousePG cluster (for example, `gpadmin`).
2. Run the `gpexpand` utility with the `-c` option. For example:

```
$ gpexpand -c
```

> **Note** Some systems require you to press Enter twice.

Setting Up PXF on the New Host

If you are using PXF in your WarehousePG cluster, you must perform some configuration steps on the new hosts.

There are different steps to follow depending on your PXF version and the type of installation.

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- You must install the same version of the PXF `rpm` or `deb` on the new hosts.
- Log into the WarehousePG Coordinator and run the following commands:

```
gpadmin@gpcoordinator$ pxf cluster reset
gpadmin@gpcoordinator$ pxf cluster init
```

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- You must install the same version of the PXF `rpm` or `deb` on the new hosts.
- Log into the WarehousePG Coordinator and run the following commands:

```
gpadmin@gpcoordinator$ pxf cluster register
gpadmin@gpcoordinator$ pxf cluster sync
```

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4.2.10 Monitoring a WarehousePG cluster

You can monitor a WarehousePG cluster using a variety of tools included with the system or available as add-ons.

Observing the WarehousePG cluster day-to-day performance helps administrators understand the system behavior, plan workflow, and troubleshoot problems. This chapter discusses tools for monitoring database performance and activity.

Also, be sure to review Recommended Monitoring and Maintenance Tasks for monitoring activities you can script to quickly detect problems in the system.

Parent topic: Managing a WarehousePG cluster

Monitoring System State

As a WarehousePG administrator, you must monitor the system for problem events such as a segment going down or running out of disk space on a segment host. The following topics describe how to monitor the health of a WarehousePG cluster and examine certain state information for a WarehousePG cluster.

- Checking System State
- Checking Disk Space Usage
- Checking for Data Distribution Skew
- Checking for and Terminating Overflowed Backends
- Viewing Metadata Information about Database Objects
- Viewing Session Memory Usage Information
- Viewing and Logging Per-Process Memory Usage Information
- Viewing Query Workfile Usage Information

Checking System State

A WarehousePG cluster is comprised of multiple PostgreSQL instances (the coordinator and segments) spanning multiple machines. To monitor a WarehousePG cluster, you need to know information about the system as a whole, as well as status information of the individual instances. The `gpstate` utility provides status information about a WarehousePG cluster.

Viewing Coordinator and Segment Status and Configuration

The default `gpstate` action is to check segment instances and show a brief status of the valid and failed segments. For example, to see a quick status of your WarehousePG cluster:

```
$ gpstate
```

To see more detailed information about your WarehousePG cluster configuration, use `gpstate` with the `-s` option:

```
$ gpstate -s
```

Viewing Your Mirroring Configuration and Status

If you are using mirroring for data redundancy, you may want to see the list of mirror segment instances in the system, their current synchronization status, and the mirror to primary mapping. For example, to see the mirror segments in the system and their status:

```
$ gpstate -m
```

To see the primary to mirror segment mappings:

```
$ gpstate -c
```

To see the status of the standby coordinator mirror:

```
$ gpstate -f
```

Checking Disk Space Usage

A database administrator's most important monitoring task is to make sure the file systems where the coordinator and segment data directories reside do not grow to more than 70 percent full. A filled data disk will not result in data corruption, but it may prevent normal database activity from continuing. If the disk grows too full, it can cause the database server to shut down.

You can use the `gp_disk_free` external table in the `gp_toolkit` administrative schema to check for remaining free space (in kilobytes) on the segment host file systems. For example:

```
=# SELECT * FROM gp_toolkit.gp_disk_free
   ORDER BY dfsegment;
```

Checking Sizing of Distributed Databases and Tables

The `gp_toolkit` administrative schema contains several views that you can use to determine the disk space usage for a distributed WarehousePG database, schema, table, or index.

For a list of the available sizing views for checking database object sizes and disk space, see the *WarehousePG Reference Guide*.

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Viewing Disk Space Usage for a Database

To see the total size of a database (in bytes), use the *gp_size_of_database* view in the *gp_toolkit* administrative schema. For example:

```
=> SELECT * FROM gp_toolkit.gp_size_of_database
   ORDER BY sodddatname;
```

Viewing Disk Space Usage for a Table

The *gp_toolkit* administrative schema contains several views for checking the size of a table. The table sizing views list the table by object ID (not by name). To check the size of a table by name, you must look up the relation name (`relname`) in the *pg_class* table. For example:

```
=> SELECT relname AS name, sotdsize AS size, sotdtoastsize
   AS toast, sotdadditionalsize AS other
   FROM gp_toolkit.gp_size_of_table_disk as sotd, pg_class
   WHERE sotd.sotdoid=pg_class.oid ORDER BY relname;
```

For a list of the available table sizing views, see the *WarehousePG Reference Guide*.

Viewing Disk Space Usage for Indexes

The *gp_toolkit* administrative schema contains a number of views for checking index sizes. To see the total size of all index(es) on a table, use the *gp_size_of_all_table_indexes* view. To see the size of a particular index, use the *gp_size_of_index* view. The index sizing views list tables and indexes by object ID (not by name). To check the size of an index by name, you must look up the relation name (`relname`) in the *pg_class* table. For example:

```
=> SELECT soisize, relname as indexname
   FROM pg_class, gp_toolkit.gp_size_of_index
   WHERE pg_class.oid=gp_size_of_index.soioid
   AND pg_class.relkind='i';
```

Checking for Data Distribution Skew

All tables in WarehousePG are distributed, meaning their data is divided across all of the segments in the system. Unevenly distributed data may diminish query processing performance. A table's distribution policy, set at table creation time, determines how the table's rows are distributed. For information about choosing the table distribution policy, see the following topics:

- Viewing a Table's Distribution Key
- Viewing Data Distribution
- Checking for Query Processing Skew

The *gp_toolkit* administrative schema also contains a number of views for checking data distribution skew on a table. For information about how to check for uneven data distribution, see the *WarehousePG Reference Guide*.

Viewing a Table's Distribution Key

To see the columns used as the data distribution key for a table, you can use the `\d+` meta-command in `psql` to examine the definition of a table. For example:

```
=# `\d+ sales
`                Table "retail.sales"
 Column      |     Type     | Modifiers | Description
-------------+--------------+-----------+-------------
 sale_id     | integer      |           |
 amt         | float        |           |
 date        | date         |           |
Has OIDs: no
Distributed by: (sale_id)
```

When you create a *replicated* table, WarehousePG stores all rows in the table on every segment. Replicated tables have no distribution key. Where the `\d+` meta-command reports the distribution key for a normally distributed table, it shows `Distributed Replicated` for a replicated table.

Viewing Data Distribution

To see the data distribution of a table's rows (the number of rows on each segment), you can run a query such as:

```
=# SELECT gp_segment_id, count(*)
   FROM <table_name> GROUP BY gp_segment_id;
```

A table is considered to have a balanced distribution if all segments have roughly the same number of rows.

> **Note** If you run this query on a replicated table, it fails because WarehousePG does not permit user queries to reference the system column `gp_segment_id` (or the system columns `ctid`, `cmin`, `cmax`, `xmin`, and `xmax`) in replicated tables. Because every segment has all of the tables' rows, replicated tables are evenly distributed by definition.

Checking for Query Processing Skew

When a query is being processed, all segments should have equal workloads to ensure the best possible performance. If you identify a poorly-performing query, you may need to investigate further using the `EXPLAIN` command. For information about using the `EXPLAIN` command and query profiling, see Query Profiling.

Query processing workload can be skewed if the table's data distribution policy and the query predicates are not well matched. To check for processing skew, you can run a query such as:

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```
=# SELECT gp_segment_id, count(*) FROM <table_name>
   WHERE <column>='<value>' GROUP BY gp_segment_id;
```

This will show the number of rows returned by segment for the given `WHERE` predicate.

As noted in Viewing Data Distribution, this query will fail if you run it on a replicated table because you cannot reference the `gp_segment_id` system column in a query on a replicated table.

Avoiding an Extreme Skew Warning

You may receive the following warning message while running a query that performs a hash join operation:

`Extreme skew in the innerside of Hashjoin`

This occurs when the input to a hash join operator is skewed. It does not prevent the query from completing successfully. You can follow these steps to avoid skew in the plan:

1. Ensure that all fact tables are analyzed.
2. Verify that any populated temporary table used by the query is analyzed.
3. View the `EXPLAIN ANALYZE` plan for the query and look for the following:
    - If there are scans with multi-column filters that are producing more rows than estimated, then set the `gp_selectivity_damping_factor` server configuration parameter to 2 or higher and retest the query.
    - If the skew occurs while joining a single fact table that is relatively small (less than 5000 rows), set the `gp_segments_for_planner` server configuration parameter to 1 and retest the query.
4. Check whether the filters applied in the query match distribution keys of the base tables. If the filters and distribution keys are the same, consider redistributing some of the base tables with different distribution keys.
5. Check the cardinality of the join keys. If they have low cardinality, try to rewrite the query with different joining columns or additional filters on the tables to reduce the number of rows. These changes could change the query semantics.

Checking for and Terminating Overflowed Backends

Subtransaction overflow arises when a WarehousePG backend creates more than 64 subtransactions, resulting in a high lookup cost for visibility checks. This slows query performance, but even more so when it occurs in combination with long-running transactions, which result in still more lookups. Terminating suboverflowed backends and/or backends with long-running transactions can help prevent and alleviate performance problems.

WarehousePG includes a view -- `gp_suboverflowed_backend` -- that is run over a user-defined function to help users query for suboverflowed backends. Users can use segment id and process id information reported in the view to terminate the offending backends, thereby preventing degradation of performance.

Steps

Follow these steps below to identify and terminate overflowed backends.

1. Select all from the view:

    ```
    select * from gp_suboverflowed_backend`;
    ```

    This returns output similar to the following:

    ```
    segid |   pids
    -------+-----------
    -1 |
     0 | {1731513}
     1 | {1731514}
     2 | {1731515}
    (4 rows)
    ```

2. Connect to the database in utility mode and query `pg_stat_activity` to return the session id for the process id in the output for a segment. For example:

    ```
    select sess_id from pg_stat_activity where pid=1731513;
    ```

    ```
    sess_id
    ---------
      10
    (1 row)
    ```

3. Terminate the session, which will terminate all associated backends on all segments:

    ```
    select pg_terminate_backend(pid) from pg_stat_activity where sess_id=10;
    ```

4. Verify that there are no more suboverflowed backends:

    ```
    select * from gp_suboverflowed_backend`;
    ```

    ```
    segid |   pids
    -------+-----------
    -1 |
     0 |
     1 |
     2 |
    (4 rows)
    ```

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Viewing Metadata Information about Database Objects

WarehousePG tracks various metadata information in its system catalogs about the objects stored in a database, such as tables, views, indexes and so on, as well as global objects such as roles and tablespaces.

Viewing the Last Operation Performed

You can use the system views *pg_stat_operations* and *pg_stat_partition_operations* to look up actions performed on an object, such as a table. For example, to see the actions performed on a table, such as when it was created and when it was last vacuumed and analyzed:

```
=> SELECT schemaname as schema, objname as table,
   usename as role, actionname as action,
   subtype as type, statime as time
   FROM pg_stat_operations
   WHERE objname='cust';
 schema | table | role | action  | type  | time
--------+-------+------+---------+-------+--------------------------
  sales | cust  | main | CREATE  | TABLE | 2016-02-09 18:10:07.867977-08
  sales | cust  | main | VACUUM  |       | 2016-02-10 13:32:39.068219-08
  sales | cust  | main | ANALYZE |       | 2016-02-25 16:07:01.157168-08
(3 rows)
```

Viewing the Definition of an Object

To see the definition of an object, such as a table or view, you can use the `\d+` meta-command when working in `psql`. For example, to see the definition of a table:

```
=> \d+ <mytable>
```

Viewing Session Memory Usage Information

You can create and use the *session_level_memory_consumption* view that provides information about the current memory utilization for sessions that are running queries on WarehousePG. The view contains session information and information such as the database that the session is connected to, the query that the session is currently running, and memory consumed by the session processes.

- Creating the session_level_memory_consumption View
- The session_level_memory_consumption View

Creating the session_level_memory_consumption View

To create the *session_state.session_level_memory_consumption* view in a WarehousePG, run the script `CREATE EXTENSION gp_internal_tools;` once for each database. For example, to install the view in the database `testdb`, use this command:

```
$ psql -d testdb -c "CREATE EXTENSION gp_internal_tools;"
```

The session_level_memory_consumption View

The *session_state.session_level_memory_consumption* view provides information about memory consumption and idle time for sessions that are running SQL queries.

When resource queue-based resource management is active, the column `is_runaway` indicates whether WarehousePG considers the session a runaway session based on the vmem memory consumption of the session's queries. Under the resource queue-based resource management scheme, WarehousePG considers the session a runaway when the queries consume an excessive amount of memory. The WarehousePG server configuration parameter `runaway_detector_activation_percent` governs the conditions under which WarehousePG considers a session a runaway session.

The `is_runaway`, `runaway_vmem_mb`, and `runaway_command_cnt` columns are not applicable when resource group-based resource management is active.

column	type	references	description
`datname`	name		Name of the database that the session is connected to.
`sess_id`	integer		Session ID.
`usename`	name		Name of the session user.
`query`	text		Current SQL query that the session is running.
`segid`	integer		Segment ID.
`vmem_mb`	integer		Total vmem memory usage for the session in MB.
`is_runaway`	boolean		Session is marked as runaway on the segment.
`qe_count`	integer		Number of query processes for the session.
`active_qe_count`	integer		Number of active query processes for the session.
`dirty_qe_count`	integer		Number of query processes that have not yet released their memory. The value is `-1` for sessions that are not running.
`runaway_vmem_mb`	integer		Amount of vmem memory that the session was consuming when it was marked as a runaway session.
`runaway_command_cnt`	integer		Command count for the session when it was marked as a runaway session.
`idle_start`	timestamptz		The last time a query process in this session became idle.

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Viewing and Logging Per-Process Memory Usage Information

WarehousePG allocates all memory within memory contexts. Memory contexts provide a convenient way to manage allocations made in different places that need to live for differing amounts of time. Destroying a context releases all of the memory that was allocated in it.

Tracking the amount of memory used by a server process or a long-running query can help detect the source of a potential out-of-memory condition. WarehousePG provides a system view and administration functions that you can use for this purpose.

About the pg_backend_memory_contexts View

To display the memory usage of all active memory contexts in the server process attached to the current session, use thepg_backend_memory_contexts system view. This view is restricted to superusers, but access may be granted to other roles.

```
SELECT * FROM pg_backend_memory_contexts;
```

About the Memory Context Admin Functions

You can use the system administration function `pg_log_backend_memory_contexts()` to instruct WarehousePG to dump the memory usage of other sessions running on the coordinator host into the server log. Execution of this function is restricted to superusers only, and cannot be granted to other roles.

The signature of `pg_log_backend_memory_contexts()` function follows:

```
pg_log_backend_memory_contexts( pid integer )
```

where `pid` identifies the process whose memory contexts you want dumped.

`pg_log_backend_memory_contexts()` returns `true` when memory context logging is successfully activated for the process on the local host. When logging is activated, WarehousePG writes one message to the log for each memory context at the `LOG` message level. The log messages appear in the server log based on the log configuration set; refer to Error Reporting and Logging in the PostgreSQL documentation for more information. *The memory context log messages are not sent to the client.*

Memory context logging functions that dump memory usage across all WarehousePG segments, or dump usage for a specific segment are named `gp_log_backend_memory_contexts()`.

`gp_log_backend_memory_contexts()` has two signatures:

```
gp_log_backend_memory_contexts( sess_id integer )
gp_log_backend_memory_contexts( sess_id integer, contentId integer )
```

where `sess_id` is the WarehousePG identifier assigned to the session (typically obtained from the `pg_stat_activity` view), and `contentID` in the second signature identifies the segment instance of interest.

When you invoke `gp_log_backend_memory_contexts()` on the WarehousePG coordinator host, it invokes `pg_log_backend_memory_contexts()` on the individual segments, which in turn triggers a memory usage dump to each segment log. The functions return an integer identifying the number of segments on which memory context logging was successfully activated.

Sample Log Messages

The command:

```
SELECT pg_log_backend_memory_contexts( pg_backend_pid()
);
```

triggered the dumping of the following (subset of) memory context messages to the local server log file:

```
2023-03-23 16:45:57.228512 UTC,"gpadmin","testdb",p16389,th-557447104,"[local]",,2023-03-23 15:57:32 UTC,0,,cmd10,seg-1,,,,sx1,"LOG","00000","logging memory
contexts of PID 16389",,,,,,"SELECT pg_log_backend_memory_contexts(pg_backend_pid());",0,,"mcxt.c",1278,
2023-03-23 16:45:57.229275 UTC,"gpadmin","testdb",p16389,th-557447104,"[local]",,2023-03-23 15:57:32 UTC,0,,cmd10,seg-1,,,,sx1,"LOG","00000","level: 0;
TopMemoryContext: 108384 total in 6 blocks; 23248 free (21 chunks); 85136 used",,,,,,,0,,"mcxt.c",884,
2023-03-23 16:45:57.229822 UTC,"gpadmin","testdb",p16389,th-557447104,"[local]",,2023-03-23 15:57:32 UTC,0,,cmd10,seg-1,,,,sx1,"LOG","00000","level: 1; pgstat
TabStatusArray lookup hash table: 8192 total in 1 blocks; 1416 free (0 chunks); 6776 used",,,,,,,0,,"mcxt.c",884,
2023-03-23 16:45:57.230387 UTC,"gpadmin","testdb",p16389,th-557447104,"[local]",,2023-03-23 15:57:32 UTC,0,,cmd10,seg-1,,,,sx1,"LOG","00000","level: 1;
TopTransactionContext: 8192 total in 1 blocks; 7576 free (1 chunks); 616 used",,,,,,,0,,"mcxt.c",884,
2023-03-23 16:45:57.230961 UTC,"gpadmin","testdb",p16389,th-557447104,"[local]",,2023-03-23 15:57:32 UTC,0,,cmd10,seg-1,,,,sx1,"LOG","00000","level: 1; TableSpace
cache: 8192 total in 1 blocks; 2056 free (0 chunks); 6136 used",,,,,,,0,,"mcxt.c",884,
```

Viewing Query Workfile Usage Information

The WarehousePG administrative schema *gp_toolkit* contains views that display information about WarehousePG workfiles. WarehousePG creates workfiles on disk if it does not have sufficient memory to run the query in memory. This information can be used for troubleshooting and tuning queries. The information in the views can also be used to specify the values for the WarehousePG configuration parameters `gp_workfile_limit_per_query` and `gp_workfile_limit_per_segment`.

These are the views in the schema *gp_toolkit*:

- The gp_workfile_entries view contains one row for each operator using disk space for workfiles on a segment at the current time.
- The gp_workfile_usage_per_query view contains one row for each query using disk space for workfiles on a segment at the current time.
- The gp_workfile_usage_per_segment view contains one row for each segment. Each row displays the total amount of disk space used for workfiles on the segment at the current time.

For information about using *gp_toolkit*, see Using gp_toolkit.

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Viewing the Database Server Log Files

Every database instance in WarehousePG (coordinator and segments) runs a PostgreSQL database server with its own server log file. Log files are created in the `log` directory of the coordinator and each segment data directory.

Log File Format

The server log files are written in comma-separated values (CSV) format. Some log entries will not have values for all log fields. For example, only log entries associated with a query worker process will have the `slice_id` populated. You can identify related log entries of a particular query by the query's session identifier (`gp_session_id`) and command identifier (`gp_command_count`).

The following fields are written to the log:

Number	Field Name	Data Type	Description
1	event_time	timestamp with time zone	Time that the log entry was written to the log
2	user_name	varchar(100)	The database user name
3	database_name	varchar(100)	The database name
4	process_id	varchar(10)	The system process ID (prefixed with "p")
5	thread_id	varchar(50)	The thread count (prefixed with "th")
6	remote_host	varchar(100)	On the coordinator, the hostname/address of the client machine. On the segment, the hostname/address of the coordinator.
7	remote_port	varchar(10)	The segment or coordinator port number
8	session_start_time	timestamp with time zone	Time session connection was opened
9	transaction_id	int	Top-level transaction ID on the coordinator. This ID is the parent of any subtransactions.
10	gp_session_id	text	Session identifier number (prefixed with "con")
11	gp_command_count	text	The command number within a session (prefixed with "cmd")
12	gp_segment	text	The segment content identifier (prefixed with "seg" for primaries or "mir" for mirrors). The coordinator always has a content ID of -1.
13	slice_id	text	The slice ID (portion of the query plan being executed)
14	distr_tranx_id	text	Distributed transaction ID
15	local_tranx_id	text	Local transaction ID
16	sub_tranx_id	text	Subtransaction ID
17	event_severity	varchar(10)	Values include: LOG, ERROR, FATAL, PANIC, DEBUG1, DEBUG2
18	sql_state_code	varchar(10)	SQL state code associated with the log message
19	event_message	text	Log or error message text
20	event_detail	text	Detail message text associated with an error or warning message
21	event_hint	text	Hint message text associated with an error or warning message
22	internal_query	text	The internally-generated query text
23	internal_query_pos	int	The cursor index into the internally-generated query text
24	event_context	text	The context in which this message gets generated
25	debug_query_string	text	User-supplied query string with full detail for debugging. This string can be modified for internal use.
26	error_cursor_pos	int	The cursor index into the query string
27	func_name	text	The function in which this message is generated
28	file_name	text	The internal code file where the message originated
29	file_line	int	The line of the code file where the message originated
30	stack_trace	text	Stack trace text associated with this message

Searching the WarehousePG Server Log Files

WarehousePG provides a utility called `gplogfilter` can search through a WarehousePG log file for entries matching the specified criteria. By default, this utility searches through the WarehousePG coordinator log file in the default logging location. For example, to display the last three lines of each of the log files under the coordinator directory:

```
$ gplogfilter -n 3
```

To search through all segment log files simultaneously, run `gplogfilter` through the `gpssh` utility. For example, to display the last three lines of each segment log file:

```
$ gpssh -f seg_host_file
```

```
=> source /usr/edb/whpg7/greenplum_path.sh
=> gplogfilter -n 3 /gpdata/gp*/log/gpdb*.log
```

Using gp_toolkit

Use the WarehousePG administrative schema *gp_toolkit* to query the system catalogs, log files, and operating environment for system status information. The `gp_toolkit` schema contains several views you can access using SQL commands. The *gp_toolkit* schema is accessible to all database users. Some objects require superuser permissions. Use a command similar to the following to add the *gp_toolkit* schema to your schema search path:

```
=> ALTER ROLE myrole SET search_path TO myschema,gp_toolkit;
```

For a description of the available administrative schema views and their usages, see the *WarehousePG Reference Guide*.

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SQL Standard Error Codes

The following table lists all the defined error codes. Some are not used, but are defined by the SQL standard. The error classes are also shown. For each error class there is a standard error code having the last three characters 000. This code is used only for error conditions that fall within the class but do not have any more-specific code assigned.

The PL/pgSQL condition name for each error code is the same as the phrase shown in the table, with underscores substituted for spaces. For example, code 22012, DIVISION BY ZERO, has condition name DIVISION_BY_ZERO. Condition names can be written in either upper or lower case.

> **Note** PL/pgSQL does not recognize warning, as opposed to error, condition names; those are classes 00, 01, and 02.

Error Code	Meaning	Constant
Class 00— Successful Completion		
00000	SUCCESSFUL COMPLETION	successful_completion
Class 01 — Warning		
01000	WARNING	warning
0100C	DYNAMIC RESULT SETS RETURNED	dynamic_result_sets_returned
01008	IMPLICIT ZERO BIT PADDING	implicit_zero_bit_padding
01003	NULL VALUE ELIMINATED IN SET FUNCTION	null_value_eliminated_in_set_function
01007	PRIVILEGE NOT GRANTED	privilege_not_granted
01006	PRIVILEGE NOT REVOKED	privilege_not_revoked
01004	STRING DATA RIGHT TRUNCATION	string_data_right_truncation
01P01	DEPRECATED FEATURE	deprecated_feature
Class 02 — No Data (this is also a warning class per the SQL standard)		
02000	NO DATA	no_data
02001	NO ADDITIONAL DYNAMIC RESULT SETS RETURNED	no_additional_dynamic_result_sets_returned
Class 03 — SQL Statement Not Yet Complete		
03000	SQL STATEMENT NOT YET COMPLETE	sql_statement_not_yet_complete
Class 08 — Connection Exception		
08000	CONNECTION EXCEPTION	connection_exception
08003	CONNECTION DOES NOT EXIST	connection_does_not_exist
08006	CONNECTION FAILURE	connection_failure
08001	SQLCLIENT UNABLE TO ESTABLISH SQLCONNECTION	sqlclient_unable_to_establish_sqlconnection
08004	SQLSERVER REJECTED ESTABLISHMENT OF SQLCONNECTION	sqlserver_rejected_establishment_of_sqlconnection
08007	TRANSACTION RESOLUTION UNKNOWN	transaction_resolution_unknown
08P01	PROTOCOL VIOLATION	protocol_violation
Class 09 — Triggered Action Exception		
09000	TRIGGERED ACTION EXCEPTION	triggered_action_exception
Class 0A — Feature Not Supported		
0A000	FEATURE NOT SUPPORTED	feature_not_supported
Class 0B — Invalid Transaction Initiation		
0B000	INVALID TRANSACTION INITIATION	invalid_transaction_initiation
Class 0F — Locator Exception		
0F000	LOCATOR EXCEPTION	locator_exception
0F001	INVALID LOCATOR SPECIFICATION	invalid_locator_specification
Class 0L — Invalid Grantor		
0L000	INVALID GRANTOR	invalid_grantor
0LP01	INVALID GRANT OPERATION	invalid_grant_operation
Class 0P — Invalid Role Specification		
0P000	INVALID ROLE SPECIFICATION	invalid_role_specification
Class 21 — Cardinality Violation		
21000	CARDINALITY VIOLATION	cardinality_violation
Class 22 — Data Exception		
22000	DATA EXCEPTION	data_exception
2202E	ARRAY SUBSCRIPT ERROR	array_subscript_error
22021	CHARACTER NOT IN REPERTOIRE	character_not_in_repertoire
22008	DATETIME FIELD OVERFLOW	datetime_field_overflow
22012	DIVISION BY ZERO	division_by_zero
22005	ERROR IN ASSIGNMENT	error_in_assignment
2200B	ESCAPE CHARACTER CONFLICT	escape_character_conflict
22022	INDICATOR OVERFLOW	indicator_overflow
22015	INTERVAL FIELD OVERFLOW	interval_field_overflow
2201E	INVALID ARGUMENT FOR LOGARITHM	invalid_argument_for_logarithm
2201F	INVALID ARGUMENT FOR POWER FUNCTION	invalid_argument_for_power_function
2201G	INVALID ARGUMENT FOR WIDTH BUCKET FUNCTION	invalid_argument_for_width_bucket_function
22018	INVALID CHARACTER VALUE FOR CAST	invalid_character_value_for_cast
22007	INVALID DATETIME FORMAT	invalid_datetime_format
22019	INVALID ESCAPE CHARACTER	invalid_escape_character
2200D	INVALID ESCAPE OCTET	invalid_escape_octet
22025	INVALID ESCAPE SEQUENCE	invalid_escape_sequence
22P06	NONSTANDARD USE OF ESCAPE CHARACTER	nonstandard_use_of_escape_character
22010	INVALID INDICATOR PARAMETER VALUE	invalid_indicator_parameter_value

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Error Code	Meaning	Constant
22020	INVALID LIMIT VALUE	invalid_limit_value
22023	INVALID PARAMETER VALUE	invalid_parameter_value
2201B	INVALID REGULAR EXPRESSION	invalid_regular_expression
22009	INVALID TIME ZONE DISPLACEMENT VALUE	invalid_time_zone_displacement_value
2200C	INVALID USE OF ESCAPE CHARACTER	invalid_use_of_escape_character
2200G	MOST SPECIFIC TYPE MISMATCH	most_specific_type_mismatch
22004	NULL VALUE NOT ALLOWED	null_value_not_allowed
22002	NULL VALUE NO INDICATOR PARAMETER	null_value_no_indicator_parameter
22003	NUMERIC VALUE OUT OF RANGE	numeric_value_out_of_range
22026	STRING DATA LENGTH MISMATCH	string_data_length_mismatch
22001	STRING DATA RIGHT TRUNCATION	string_data_right_truncation
22011	SUBSTRING ERROR	substring_error
22027	TRIM ERROR	trim_error
22024	UNTERMINATED C STRING	unterminated_c_string
2200F	ZERO LENGTH CHARACTER STRING	zero_length_character_string
22P01	FLOATING POINT EXCEPTION	floating_point_exception
22P02	INVALID TEXT REPRESENTATION	invalid_text_representation
22P03	INVALID BINARY REPRESENTATION	invalid_binary_representation
22P04	BAD COPY FILE FORMAT	bad_copy_file_format
22P05	UNTRANSLATABLE CHARACTER	untranslatable_character
Class 23 — Integrity Constraint Violation		
23000	INTEGRITY CONSTRAINT VIOLATION	integrity_constraint_violation
23001	RESTRICT VIOLATION	restrict_violation
23502	NOT NULL VIOLATION	not_null_violation
23503	FOREIGN KEY VIOLATION	foreign_key_violation
23505	UNIQUE VIOLATION	unique_violation
23514	CHECK VIOLATION	check_violation
Class 24 — Invalid Cursor State		
24000	INVALID CURSOR STATE	invalid_cursor_state
Class 25 — Invalid Transaction State		
25000	INVALID TRANSACTION STATE	invalid_transaction_state
25001	ACTIVE SQL TRANSACTION	active_sql_transaction
25002	BRANCH TRANSACTION ALREADY ACTIVE	branch_transaction_already_active
25008	HELD CURSOR REQUIRES SAME ISOLATION LEVEL	held_cursor_requires_same_isolation_level
25003	INAPPROPRIATE ACCESS MODE FOR BRANCH TRANSACTION	inappropriate_access_mode_for_branch_transaction
25004	INAPPROPRIATE ISOLATION LEVEL FOR BRANCH TRANSACTION	inappropriate_isolation_level_for_branch_transaction
25005	NO ACTIVE SQL TRANSACTION FOR BRANCH TRANSACTION	no_active_sql_transaction_for_branch_transaction
25006	READ ONLY SQL TRANSACTION	read_only_sql_transaction
25007	SCHEMA AND DATA STATEMENT MIXING NOT SUPPORTED	schema_and_data_statement_mixing_not_supported
25P01	NO ACTIVE SQL TRANSACTION	no_active_sql_transaction
25P02	IN FAILED SQL TRANSACTION	in_failed_sql_transaction
Class 26 — Invalid SQL Statement Name		
26000	INVALID SQL STATEMENT NAME	invalid_sql_statement_name
Class 27 — Triggered Data Change Violation		
27000	TRIGGERED DATA CHANGE VIOLATION	triggered_data_change_violation
Class 28 — Invalid Authorization Specification		
28000	INVALID AUTHORIZATION SPECIFICATION	invalid_authorization_specification
Class 2B — Dependent Privilege Descriptors Still Exist		
2B000	DEPENDENT PRIVILEGE DESCRIPTORS STILL EXIST	dependent_privilege_descriptors_still_exist
2BP01	DEPENDENT OBJECTS STILL EXIST	dependent_objects_still_exist
Class 2D — Invalid Transaction Termination		
2D000	INVALID TRANSACTION TERMINATION	invalid_transaction_termination
Class 2F — SQL Routine Exception		
2F000	SQL ROUTINE EXCEPTION	sql_routine_exception
2F005	FUNCTION EXECUTED NO RETURN STATEMENT	function_executed_no_return_statement
2F002	MODIFYING SQL DATA NOT PERMITTED	modifying_sql_data_not_permitted
2F003	PROHIBITED SQL STATEMENT ATTEMPTED	prohibited_sql_statement_attempted
2F004	READING SQL DATA NOT PERMITTED	reading_sql_data_not_permitted
Class 34 — Invalid Cursor Name		
34000	INVALID CURSOR NAME	invalid_cursor_name
Class 38 — External Routine Exception		
38000	EXTERNAL ROUTINE EXCEPTION	external_routine_exception
38001	CONTAINING SQL NOT PERMITTED	containing_sql_not_permitted
38002	MODIFYING SQL DATA NOT PERMITTED	modifying_sql_data_not_permitted
38003	PROHIBITED SQL STATEMENT ATTEMPTED	prohibited_sql_statement_attempted
38004	READING SQL DATA NOT PERMITTED	reading_sql_data_not_permitted
Class 39 — External Routine Invocation Exception		
39000	EXTERNAL ROUTINE INVOCATION EXCEPTION	external_routine_invocation_exception

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Error Code	Meaning	Constant
39001	INVALID SQLSTATE RETURNED	invalid_sqlstate_returned
39004	NULL VALUE NOT ALLOWED	null_value_not_allowed
39P01	TRIGGER PROTOCOL VIOLATED	trigger_protocol_violated
39P02	SRF PROTOCOL VIOLATED	srf_protocol_violated
Class 3B — Savepoint Exception		
3B000	SAVEPOINT EXCEPTION	savepoint_exception
3B001	INVALID SAVEPOINT SPECIFICATION	invalid_savepoint_specification
Class 3D — Invalid Catalog Name		
3D000	INVALID CATALOG NAME	invalid_catalog_name
Class 3F — Invalid Schema Name		
3F000	INVALID SCHEMA NAME	invalid_schema_name
Class 40 — Transaction Rollback		
40000	TRANSACTION ROLLBACK	transaction_rollback
40002	TRANSACTION INTEGRITY CONSTRAINT VIOLATION	transaction_integrity_constraint_violation
40001	SERIALIZATION FAILURE	serialization_failure
40003	STATEMENT COMPLETION UNKNOWN	statement_completion_unknown
40P01	DEADLOCK DETECTED	deadlock_detected
Class 42 — Syntax Error or Access Rule Violation		
42000	SYNTAX ERROR OR ACCESS RULE VIOLATION	syntax_error_or_access_rule_violation
42601	SYNTAX ERROR	syntax_error
42501	INSUFFICIENT PRIVILEGE	insufficient_privilege
42846	CANNOT COERCE	cannot_coerce
42803	GROUPING ERROR	grouping_error
42830	INVALID FOREIGN KEY	invalid_foreign_key
42602	INVALID NAME	invalid_name
42622	NAME TOO LONG	name_too_long
42939	RESERVED NAME	reserved_name
42804	DATATYPE MISMATCH	datatype_mismatch
42P18	INDETERMINATE DATATYPE	indeterminate_datatype
42809	WRONG OBJECT TYPE	wrong_object_type
42703	UNDEFINED COLUMN	undefined_column
42883	UNDEFINED FUNCTION	undefined_function
42P01	UNDEFINED TABLE	undefined_table
42P02	UNDEFINED PARAMETER	undefined_parameter
42704	UNDEFINED OBJECT	undefined_object
42701	DUPLICATE COLUMN	duplicate_column
42P03	DUPLICATE CURSOR	duplicate_cursor
42P04	DUPLICATE DATABASE	duplicate_database
42723	DUPLICATE FUNCTION	duplicate_function
42P05	DUPLICATE PREPARED STATEMENT	duplicate_prepared_statement
42P06	DUPLICATE SCHEMA	duplicate_schema
42P07	DUPLICATE TABLE	duplicate_table
42712	DUPLICATE ALIAS	duplicate_alias
42710	DUPLICATE OBJECT	duplicate_object
42702	AMBIGUOUS COLUMN	ambiguous_column
42725	AMBIGUOUS FUNCTION	ambiguous_function
42P08	AMBIGUOUS PARAMETER	ambiguous_parameter
42P09	AMBIGUOUS ALIAS	ambiguous_alias
42P10	INVALID COLUMN REFERENCE	invalid_column_reference
42611	INVALID COLUMN DEFINITION	invalid_column_definition
42P11	INVALID CURSOR DEFINITION	invalid_cursor_definition
42P12	INVALID DATABASE DEFINITION	invalid_database_definition
42P13	INVALID FUNCTION DEFINITION	invalid_function_definition
42P14	INVALID PREPARED STATEMENT DEFINITION	invalid_prepared_statement_definition
42P15	INVALID SCHEMA DEFINITION	invalid_schema_definition
42P16	INVALID TABLE DEFINITION	invalid_table_definition
42P17	INVALID OBJECT DEFINITION	invalid_object_definition
Class 44 — WITH CHECK OPTION Violation		
44000	WITH CHECK OPTION VIOLATION	with_check_option_violation
Class 53 — Insufficient Resources		
53000	INSUFFICIENT RESOURCES	insufficient_resources
53100	DISK FULL	disk_full
53200	OUT OF MEMORY	out_of_memory
53300	TOO MANY CONNECTIONS	too_many_connections
Class 54 — Program Limit Exceeded		
54000	PROGRAM LIMIT EXCEEDED	program_limit_exceeded
54001	STATEMENT TOO COMPLEX	statement_too_complex
54011	TOO MANY COLUMNS	too_many_columns

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Error Code	Meaning	Constant
54023	TOO MANY ARGUMENTS	too_many_arguments
Class 55 — Object Not In Prerequisite State		
55000	OBJECT NOT IN PREREQUISITE STATE	object_not_in_prerequisite_state
55006	OBJECT IN USE	object_in_use
55P02	CANT CHANGE RUNTIME PARAM	cant_change_runtime_param
55P03	LOCK NOT AVAILABLE	lock_not_available
Class 57 — Operator Intervention		
57000	OPERATOR INTERVENTION	operator_intervention
57014	QUERY CANCELED	query_canceled
57P01	ADMIN SHUTDOWN	admin_shutdown
57P02	CRASH SHUTDOWN	crash_shutdown
57P03	CANNOT CONNECT NOW	cannot_connect_now
Class 58 — System Error (errors external to WarehousePG)		
58030	IO ERROR	io_error
58P01	UNDEFINED FILE	undefined_file
58P02	DUPLICATE FILE	duplicate_file
Class F0 — Configuration File Error		
F0000	CONFIG FILE ERROR	config_file_error
F0001	LOCK FILE EXISTS	lock_file_exists
Class P0 — PL/pgSQL Error		
P0000	PLPGSQL ERROR	plpgsql_error
P0001	RAISE EXCEPTION	raise_exception
P0002	NO DATA FOUND	no_data_found
P0003	TOO MANY ROWS	too_many_rows
Class XX — Internal Error		
XX000	INTERNAL ERROR	internal_error
XX001	DATA CORRUPTED	data_corrupted
XX002	INDEX CORRUPTED	index_corrupted

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4.2.11 Monitoring Long-Running Operations

WarehousePG can report the progress of `ANALYZE`, `CLUSTER`, `COPY`, `CREATE INDEX`, `REINDEX`, and `VACUUM` commands during command execution. WarehousePG can also report the progress of a running base backup (initiated during gprecoverseg -F) command invocation, allowing you to monitor the progress of these possibly long-running operations.

WarehousePG reports the command progress via ephemeral system views, which return data only while the operations are running. Two sets of progress reporting views are provided:

- `gp_stat_progress_<command>` - displays the progress of running `<command>` invocations on the coordinator and all segments, with a row per segment instance
- `gp_stat_progress_<command>_summary` - aggregates `<command>` progress on the coordinator and all segments, and displays one row per running `<command>` invocation

WarehousePG reports progress in phases, where the phases are specific to the command. For example, `acquiring sample rows` is an analyze progress phase, while `building index` is an index creation progress phase. WarehousePG reports the progress for both heap and AO/CO tables. For most commands, heap and AO/CO table share the same phases. For vacuum and cluster operations, WarehousePG reports heap and AO/CO table progress in separate phases.

ANALYZE Progress Reporting

The gp_stat_progress_analyze system view reports the progress of running `ANALYZE` and `analyzedb` operations. The view displays a row per segment instance that is currently servicing an analyze operation.

For each active analyze operation, the `gp_stat_progress_analyze_summary` view aggregates across the WarehousePG cluster the metrics reported by `gp_stat_progress_analyze`.

The table below describes how to interpret the phase-specific information reported in the views:

Phase	Description
`initializing`	The command is preparing to begin scanning the heap. This phase is expected to be very brief.
`acquiring sample rows`	The command is currently scanning the table given by `relid` to obtain sample rows.
`acquiring inherited sample rows`	The command is currently scanning child tables to obtain sample rows. Columns `child_tables_total`, `child_tables_done`, and `current_child_table_relid` contain the progress information for this phase.
`computing statistics`	The command is computing statistics from the sample rows obtained during the table scan.
`computing extended statistics`	The command is computing extended statistics from the sample rows obtained during the table scan.
`finalizing analyze`	The command is updating `pg_class`. When this phase is completed, `ANALYZE` ends.

CLUSTER and VACUUM FULL Progress Reporting

The gp_stat_progress_cluster system view reports the progress of running `CLUSTER`, `clusterdb`, and `VACUUM FULL` (on a heap table) operations. (`VACUUM FULL` on a heap table is similar to `CLUSTER` in that WarehousePG performs a re-write of the table.) The view displays a row per segment instance that is currently servicing any of the mentioned commands.

For each active cluster or vacuum full operation, the `gp_stat_progress_cluster_summary` view aggregates across the WarehousePG cluster the metrics reported by `gp_stat_progress_cluster`.

Heap Table Cluster Phases

The table below describes how to interpret the *heap table* phase-specific information reported in the views:

Phase	Description
`initializing`	The command is preparing to begin scanning the heap. This phase is expected to be very brief.
`seq scanning heap`	The command is currently scanning the table using a sequential scan.
`index scanning heap`	`CLUSTER` is currently scanning the table using an index scan.
`sorting tuples`	`CLUSTER` is currently sorting tuples.
`writing new heap`	`CLUSTER` is currently writing the new heap.
`swapping relation files`	The command is currently swapping newly-built files into place.
`rebuilding index`	The command is currently rebuilding an index.
`performing final cleanup`	The command is performing final cleanup. When this phase is completed, `CLUSTER` or `VACUUM FULL` ends.

AO/CO Table Cluster Phases

The table below describes how to interpret the *AO/CO table* phase-specific information reported in the views:

Phase	Description
`initializing`	The command is preparing to begin scanning. This phase is expected to be very brief.
`seq scanning append-optimized`	The command is currently scanning the AO/CO table using a sequential scan.
`index scanning heap`	`CLUSTER` is currently scanning the table using an index scan.
`sorting tuples`	`CLUSTER` is currently sorting tuples.
`writing new append-optimized`	`CLUSTER` is currently writing the new AO/CO table.
`swapping relation files`	The command is currently swapping newly-built files into place.
`performing final cleanup`	The command is performing final cleanup. When this phase is completed, `CLUSTER` or `VACUUM FULL` ends.

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COPY Progress Reporting

The gp_stat_progress_copy system view reports the progress of running `COPY` operations. The view displays a row per segment instance that is currently servicing a copy operation.

For each active copy operation, the `gp_stat_progress_copy_summary` aggregates across the WarehousePG cluster the metrics reported by `gp_stat_progress_copy`.

You can also use these views to monitor the data movement progress of utilities that use `COPY` under the hood, such as `gpbackup/gprestore`.

WarehousePG calculates the `bytes_processed`, `bytes_total`, `tuples_processed`, and `tuples_excluded` column values differently for the `gp_stat_progress_copy_summary` view depending on the type of table and type of `COPY` operation. The table below identifies the table types, the types of `COPY` operations, and which of `sum()` or `average()` WarehousePG uses to calculate the final value:

Table type	COPY TO	COPY FROM	COPY TO/FROM ON SEGMENT
Distributed table	`sum()`	`sum()`	`sum()`
Replicated table	`sum()`	`average()`	`sum()`

WarehousePG uses `sum()` for `COPY ... ON SEGMENT` as the command explicitly operates on each segment irrespective of the table type.

WarehousePG uses `sum()` for `COPY TO` with replicated tables, as the actual copy originates from only a single segment.

CREATE INDEX Progress Reporting

The gp_stat_progress_create_index system view reports the progress of running `CREATE INDEX` and `REINDEX` operations. The view displays a row per segment instance that is currently servicing either command.

For each active index operation, the `gp_stat_progress_create_index_summary` view aggregates across the WarehousePG cluster the metrics reported by `gp_stat_progress_create_index`.

The table below describes how to interpret the phase-specific information reported in the views:

Phase	Description
`initializing`	`CREATE INDEX` or `REINDEX` is preparing to create the index. This phase is expected to be very brief.
`waiting for writers before build`	This phase is not applicable, WarehousePG does not support `CREATE INDEX CONCURRENTLY` or `REINDEX CONCURRENTLY`.
`building index`	The index is being built by the access method-specific code. In this phase, access methods that support progress reporting fill in their own progress data, and the subphase is indicated in this column. Typically, `blocks_total` and `blocks_done` will contain progress data, as well as potentially `tuples_total` and `tuples_done`.
`waiting for writers before validation`	This phase is not applicable, WarehousePG does not support `CREATE INDEX CONCURRENTLY` or `REINDEX CONCURRENTLY`.
`index validation: scanning index`	This phase is not applicable, WarehousePG does not support `CREATE INDEX CONCURRENTLY` or `REINDEX CONCURRENTLY`.
`index validation: sorting tuples`	This phase is not applicable, WarehousePG does not support `CREATE INDEX CONCURRENTLY` or `REINDEX CONCURRENTLY`.
`index validation: scanning table`	This phase is not applicable, WarehousePG does not support `CREATE INDEX CONCURRENTLY` or `REINDEX CONCURRENTLY`.
`waiting for old snapshots`	This phase is not applicable, WarehousePG does not support `CREATE INDEX CONCURRENTLY` or `REINDEX CONCURRENTLY`.
`waiting for readers before marking dead`	This phase is not applicable, WarehousePG does not support `REINDEX CONCURRENTLY`.
`waiting for readers before dropping`	This phase is not applicable, WarehousePG does not support `REINDEX CONCURRENTLY`.

WarehousePG skips several phases because it does not support concurrent index creation or concurrent reindexing.

VACUUM Progress Reporting

The gp_stat_progress_vacuum system view reports the progress of running `VACUUM` and `vacuumdb` operations on AO/CO and heap tables, and `VACUUM FULL` operations on AO/CO tables. The view displays a row per segment instance that is currently servicing a vacuum operation.

For each active vacuum operation, the `gp_stat_progress_vacuum_summary` view aggregates across the WarehousePG cluster the metrics reported by `gp_stat_progress_vacuum`.

Regular `VACUUM` modifies a heap table in place. `VACUUM FULL` on a heap table rewrites the table as does a `CLUSTER` operation. For information about progress reporting for `VACUUM FULL` on a heap table, see CLUSTER and VACUUM FULL Progress Reporting.

In WarehousePG, an AO/CO table vacuum behaves differently than a heap table vacuum. Because WarehousePG stores the logical EOF for each segment file, it does not need to scan physical blocks after the logical EOF, so WarehousePG can truncate them. WarehousePG always rewrites data into new segment files to get rid of dead tuples for AO/CO tables, and performs the same operations for both `VACUUM FULL` and `VACUUM`. Due to these difference, WarehousePG reports vacuum progress on heap and AO/CO tables using different phases.

Heap Table Vacuum Phases

The table below describes how to interpret the *heap table* phase-specific information reported in the views:

Heap Table Phase	Description
`initializing`	`VACUUM` is preparing to begin scanning the heap. This phase is expected to be very brief.

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Heap Table Phase	Description
`scanning heap`	`VACUUM` is currently scanning the heap. It prunes and defragment seach page if required, and possibly performs freezing activity. Use the `heap_blks_scanned` column to monitor the progress of the scan.
`vacuuming indexes`	`VACUUM` is currently vacuuming the indexes. If a table has any indexes, this will happen at least once per vacuum, after the heap has been completely scanned. It may happen multiple times per vacuum if `maintenance_work_mem` (or, in the case of autovacuum, `autovacuum_work_mem` if set) is insufficient to store the number of dead tuples found.
`vacuuming heap`	`VACUUM` is currently vacuuming the heap. Vacuuming the heap is distinct from scanning the heap, and occurs after each instance of vacuuming indexes. If `heap_blks_scanned` is less than `heap_blks_total`, the system returns to scanning the heap after this phase is completed; otherwise, it begins cleaning up indexes after this phase is completed.
`cleaning up indexes`	`VACUUM` is currently cleaning up indexes. This occurs after the heap has been completely scanned and all vacuuming of the indexes and the heap has been completed.
`truncating heap`	`VACUUM` is currently truncating the heap so as to return empty pages at the end of the relation to the operating system. This occurs after cleaning up indexes.
`performing final cleanup`	`VACUUM` is performing final cleanup. During this phase, `VACUUM` will vacuum the free space map, update statistics in `pg_class`, and report statistics to the statistics collector. When this phase is completed, the `VACUUM` operation ends.

AO/CO Table Vacuum Phases

The table below describes how to interpret the *AO/CO table* phase-specific information reported in the views:

AO/CO Table Phase	Description
`initializing`	`VACUUM` is preparing to begin scanning AO/CO tables. This phase is expected to be very brief.
`vacuuming indexes`	For AO/CO tables, the `vacuuming indexes` phase is a sub-phase that may occur during both `append-optimized pre-cleanup` and `append-optimized post-cleanup` phases if the relation has an index and there are invisible awaiting-drop segment files.
`append-optimized pre-cleanup`	`VACUUM` is performing pre-cleanup of the AO/CO table; this includes recycling `AWAITING_DROP` segments that are no longer visible to anyone from previous `VACUUM` operations, and truncating all live segment files to their logcial EOFs. Use `heap_blks_vacuumed` and `index_vacuum_count` to monitor the progress.
`append-optimized compact`	`VACUUM` is vacuuming (or "compacting") the AO/CO table by scanning the segment files and rewriting only the surviving tuples into new segment files. Use `heap_blks_scanned` and `num_dead_tuples` to monitor the progress.
`append-optimized post-cleanup`	`VACUUM` is performing post-cleanup of the AO/CO table; this includes recycling old segments that are no longer visible after the "compact" phase, and truncating all live segment files to their logcial EOFs. Use `heap_blks_vacuumed` and `index_vacuum_count` to monitor the progress.

Base Backup Progress Reporting

The gp_stat_progress_basebackup system view reports the progress of running base backup operations, as is performed by `gprecoverseg -F` (full recovery). The view displays a row per segment instance that is currently servicing replication commands.

For each active base backup operation, the `gp_stat_progress_basebackup_summary` view aggregates across the WarehousePG cluster the metrics reported by `gp_stat_progress_basebackup`.

The table below describes how to interpret the phase-specific information reported in the views:

Phase	Description
`initializing`	The WAL sender process is preparing to begin the backup. This phase is expected to be very brief.
`waiting for checkpoint to finish`	The WAL sender process is currently performing `pg_backup_start` to prepare to take a base backup, and waiting for the start-of-backup checkpoint to finish.
`estimating backup size`	The WAL sender process is currently estimating the total amount of database files that will be streamed as a base backup.
`streaming database files`	The WAL sender process is currently streaming database files as a base backup.
`waiting for wal archiving to finish`	The WAL sender process is currently performing `pg_backup_stop` to finish the backup, and waiting for all the WAL files required for the base backup to be successfully archived. The backup ends when this phase is completed.
`transferring wal files`	The WAL sender process is currently transferring all WAL logs generated during the backup. This phase may occur after `waiting for wal archiving to finish` phase. The backup ends when this phase is completed.

Example: Viewing Real-Time Command Progress

The following example commands display the real-time progress of all running `VACUUM` commands every 0.5 seconds:

```
host$ cat > viewer.sql << EOF
SELECT * FROM gp_stat_progress_vacuum ORDER BY gp_segment_id;
SELECT * FROM gp_stat_progress_vacuum_summary;
EOF

host$ watch -n 0.5 "psql -af viewer.sql"
```

Additional Considerations

Take note of these additional considerations related to progress reporting in WarehousePG:

- Progress phases and their interpretation of attributes are slightly different for AO/AOCO tables and heap tables for the `CREATE INDEX/REINDEX`, `VACUUM`, and `CLUSTER` operations. Refer to the individual command topics for more information.
- The progress views for an `ANALYZE` operation on a partitioned table display the progress of each individual leaf partition. WarehousePG does not currently provide a measure of the combined progress of all partitions.
- WarehousePG does not support the `CLUSTER` operation on a partitioned table.

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4.2.12 Routine System Maintenance Tasks

To keep a WarehousePG cluster running efficiently, the database must be regularly cleared of expired data and the table statistics must be updated so that the query optimizer has accurate information.

WarehousePG requires that certain tasks be performed regularly to achieve optimal performance. The tasks discussed here are required, but database administrators can automate them using standard UNIX tools such as `cron` scripts. An administrator sets up the appropriate scripts and checks that they ran successfully. See Recommended Monitoring and Maintenance Tasks for additional suggested maintenance activities you can implement to keep your WarehousePG cluster running optimally.

Parent topic: Managing a WarehousePG cluster

Routine Vacuum and Analyze

The design of the MVCC transaction concurrency model used in WarehousePG means that deleted or updated data rows still occupy physical space on disk even though they are not visible to new transactions. If your database has many updates and deletes, many expired rows exist and the space they use must be reclaimed with the `VACUUM` command. The `VACUUM` command also collects table-level statistics, such as numbers of rows and pages, so it is also necessary to vacuum append-optimized tables, even when there is no space to reclaim from updated or deleted rows.

Vacuuming an append-optimized table follows a different process than vacuuming heap tables. On each segment, a new segment file is created and visible rows are copied into it from the current segment. When the segment file has been copied, the original is scheduled to be dropped and the new segment file is made available. This requires sufficient available disk space for a copy of the visible rows until the original segment file is dropped.

If the ratio of hidden rows to total rows in a segment file is less than a threshold value (10, by default), the segment file is not compacted. The threshold value can be configured with the `gp_appendonly_compaction_threshold` server configuration parameter. `VACUUM FULL` ignores the value of `gp_appendonly_compaction_threshold` and rewrites the segment file regardless of the ratio.

You can use the `__gp_aovisimap_compaction_info()` function in the *gp_toolkit* schema to investigate the effectiveness of a VACUUM operation on append-optimized tables.

For information about the `__gp_aovisimap_compaction_info()` function, see Checking Append-Optimized Tables.

`VACUUM` can be deactivated for append-optimized tables using the `gp_appendonly_compaction` server configuration parameter.

For details about vacuuming a database, see Vacuuming the Database.

For information about the `gp_appendonly_compaction_threshold` server configuration parameter and the `VACUUM` command, see the *WarehousePG Reference Guide*.

Transaction ID Management

WarehousePG's MVCC transaction semantics depend on comparing transaction ID (XID) numbers to determine visibility to other transactions. Transaction ID numbers are compared using modulo 232 arithmetic, so a WarehousePG cluster that runs more than about two billion transactions can experience transaction ID wraparound, where past transactions appear to be in the future. This means past transactions' outputs become invisible. Therefore, it is necessary to `VACUUM` every table in every database at least once per two billion transactions.

WarehousePG assigns XID values only to transactions that involve DDL or DML operations, which are typically the only transactions that require an XID.

> **Important** WarehousePG monitors transaction IDs. If you do not vacuum the database regularly, WarehousePG will generate a warning and error.

WarehousePG issues the following warning when a significant portion of the transaction IDs are no longer available and before transaction ID wraparound occurs:

```
WARNING: database "database_name" must be vacuumed within *number\_of\_transactions* transactions
```

When the warning is issued, a `VACUUM` operation is required. If a `VACUUM` operation is not performed, WarehousePG stops creating transactions when it reaches a limit prior to when transaction ID wraparound occurs. WarehousePG issues this error when it stops creating transactions to avoid possible data loss:

```
FATAL: database is not accepting commands to avoid
wraparound data loss in database "database_name"
```

The WarehousePG configuration parameter `xid_warn_limit` controls when the warning is displayed. The parameter `xid_stop_limit` controls when WarehousePG stops creating transactions.

Recovering from a Transaction ID Limit Error

When WarehousePG reaches the `xid_stop_limit` transaction ID limit due to infrequent `VACUUM` maintenance, it becomes unresponsive. To recover from this situation, perform the following steps as database administrator:

1. Shut down WarehousePG.
2. Temporarily lower the `xid_stop_limit` by 10,000,000.
3. Start WarehousePG.
4. Run `VACUUM FREEZE` on all affected databases.
5. Reset the `xid_stop_limit` to its original value.
6. Restart WarehousePG.

For information about the configuration parameters, see the *WarehousePG Reference Guide*.

For information about transaction ID wraparound see the PostgreSQL documentation.

System Catalog Maintenance

Numerous database updates with `CREATE` and `DROP` commands increase the system catalog size and affect system performance. For example, running many `DROP TABLE` statements degrades the overall system performance due to excessive data scanning during metadata operations on catalog tables. The performance loss occurs between thousands to tens of thousands of `DROP TABLE` statements, depending on the system.

You should run a system catalog maintenance procedure regularly to reclaim the space occupied by deleted objects. If a regular procedure has not been run for a long time, you may need to run a more intensive procedure to clear the system catalog. This topic describes both procedures.

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Regular System Catalog Maintenance

It is recommended that you periodically run `REINDEX` and `VACUUM` on the system catalog to clear the space that deleted objects occupy in the system indexes and tables. If regular database operations include numerous `DROP` statements, it is safe and appropriate to run a system catalog maintenance procedure with `VACUUM` daily at off-peak hours. You can do this while the system is available.

These are WarehousePG cluster catalog maintenance steps.

1. Perform a `REINDEX` on the system catalog tables to rebuild the system catalog indexes. This removes bloat in the indexes and improves `VACUUM` performance.

   > **Note** `REINDEX` causes locking of system catalog tables, which could affect currently running queries. To avoid disrupting ongoing business operations, schedule the `REINDEX` operation during a period of low activity.

2. Perform a `VACUUM` on the system catalog tables.

3. Perform an `ANALYZE` on the system catalog tables to update the catalog table statistics.

This example script performs a `REINDEX`, `VACUUM`, and `ANALYZE` of a WarehousePG cluster catalog. In the script, replace `<database-name>` with a database name.

```
#!/bin/bash
DBNAME="<database-name>"
SYSTABLES="' pg_catalog.' || relname || ';' FROM pg_class a, pg_namespace b
WHERE a.relnamespace=b.oid AND b.nspname='pg_catalog' AND a.relkind='r'"

reindexdb --system -d $DBNAME
psql -tc "SELECT 'VACUUM' || $SYSTABLES" $DBNAME | psql -a $DBNAME
analyzedb -as pg_catalog -d $DBNAME
```

> **Note** If you are performing catalog maintenance during a maintenance period and you need to stop a process due to time constraints, run the WarehousePG function `pg_cancel_backend(<PID>)` to safely stop the WarehousePG process.

Intensive System Catalog Maintenance

If system catalog maintenance has not been performed in a long time, the catalog can become bloated with dead space; this causes excessively long wait times for simple metadata operations. A wait of more than two seconds to list user tables, such as with the `\d` metacommand from within `psql`, is an indication of catalog bloat.

If you see indications of system catalog bloat, you must perform an intensive system catalog maintenance procedure with `VACUUM FULL` during a scheduled downtime period. During this period, stop all catalog activity on the system; the `VACUUM FULL` system catalog maintenance procedure takes exclusive locks against the system catalog.

Running regular system catalog maintenance procedures can prevent the need for this more costly procedure.

These are steps for intensive system catalog maintenance.

1. Stop all catalog activity on the WarehousePG cluster.
2. Perform a `REINDEX` on the system catalog tables to rebuild the system catalog indexes. This removes bloat in the indexes and improves `VACUUM` performance.
3. Perform a `VACUUM FULL` on the system catalog tables. See the following Note.
4. Perform an `ANALYZE` on the system catalog tables to update the catalog table statistics.

> **Note** The system catalog table `pg_attribute` is usually the largest catalog table. If the `pg_attribute` table is significantly bloated, a `VACUUM FULL` operation on the table might require a significant amount of time and might need to be performed separately. The presence of both of these conditions indicate a significantly bloated `pg_attribute` table that might require a long `VACUUM FULL` time:

- The `pg_attribute` table contains a large number of records.
- The diagnostic message for `pg_attribute` is `significant amount of bloat` in the `gp_toolkit.gp_bloat_diag` view.

Vacuum and Analyze for Query Optimization

WarehousePG uses a cost-based query optimizer that relies on database statistics. Accurate statistics allow the query optimizer to better estimate selectivity and the number of rows that a query operation retrieves. These estimates help it choose the most efficient query plan. The `ANALYZE` command collects column-level statistics for the query optimizer.

You can run both `VACUUM` and `ANALYZE` operations in the same command. For example:

```
=# VACUUM ANALYZE mytable;
```

Running the VACUUM ANALYZE command might produce incorrect statistics when the command is run on a table with a significant amount of bloat (a significant amount of table disk space is occupied by deleted or obsolete rows). For large tables, the `ANALYZE` command calculates statistics from a random sample of rows. It estimates the number rows in the table by multiplying the average number of rows per page in the sample by the number of actual pages in the table. If the sample contains many empty pages, the estimated row count can be inaccurate.

For a table, you can view information about the amount of unused disk space (space that is occupied by deleted or obsolete rows) in the *gp_toolkit* view *gp_bloat_diag*. If the `bdidiag` column for a table contains the value `significant amount of bloat suspected`, a significant amount of table disk space consists of unused space. Entries are added to the *gp_bloat_diag* view after a table has been vacuumed.

To remove unused disk space from the table, you can run the command VACUUM FULL on the table. Due to table lock requirements, VACUUM FULL might not be possible until a maintenance period.

As a temporary workaround, run ANALYZE to compute column statistics and then run VACUUM on the table to generate an accurate row count. This example runs ANALYZE and then VACUUM on the *cust_info* table.

```
ANALYZE cust_info;
VACUUM cust_info;
```

> **Important** If you intend to run queries on partitioned tables with GPORCA enabled (the default), you must collect statistics on the root partitioned table with the ANALYZE command. For information about GPORCA, see Overview of GPORCA.

> **Note** You can use the WarehousePG utility analyzedb to update table statistics. Tables can be analyzed concurrently. For append optimized tables, analyzedb updates statistics only if the statistics are not current. See the analyzedb utility.

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Routine Reindexing

For B-tree indexes, a freshly-constructed index is slightly faster to access than one that has been updated many times because logically adjacent pages are usually also physically adjacent in a newly built index. Reindexing older indexes periodically can improve access speed. If all but a few index keys on a page have been deleted, there will be wasted space on the index page. A reindex will reclaim that wasted space. In WarehousePG it is often faster to drop an index (`DROP INDEX`) and then recreate it (`CREATE INDEX`) than it is to use the `REINDEX` command.

For table columns with indexes, some operations such as bulk updates or inserts to the table might perform more slowly because of the updates to the indexes. To enhance performance of bulk operations on tables with indexes, you can drop the indexes, perform the bulk operation, and then re-create the index.

Managing WarehousePG Log Files

- Database Server Log Files
- Management Utility Log Files

Database Server Log Files

WarehousePG log output tends to be voluminous, especially at higher debug levels, and you do not need to save it indefinitely. Administrators should purge older log files periodically.

WarehousePG by default has log file rotation enabled for the coordinator and segment database logs. Log files are created in the `log` subdirectory of the coordinator and each segment data directory using the following naming convention: `gpdb-*YYYY*-*MM*-*DD_hhmmss*.csv`. Administrators need to implement scripts or programs to periodically clean up old log files in the `log` directory of the coordinator and each segment instance.

Log rotation can be triggered by the size of the current log file or the age of the current log file. The `log_rotation_size` configuration parameter sets the size of an individual log file that triggers log rotation. When the log file size is equal to or greater than the specified size, the file is closed and a new log file is created. The `log_rotation_size` value is specified in kilobytes. The default is 1048576 kilobytes, or 1GB. If `log_rotation_size` is set to 0, size-based rotation is deactivated.

The `log_rotation_age` configuration parameter specifies the age of a log file that triggers rotation. When the specified amount of time has elapsed since the log file was created, the file is closed and a new log file is created. The default `log_rotation_age`, `1d`, creates a new log file 24 hours after the current log file was created. If `log_rotation_age` is set to 0, time-based rotation is deactivated.

For information about viewing the database server log files, see Viewing the Database Server Log Files.

Management Utility Log Files

Log files for the WarehousePG management utilities are written to `~/gpAdminLogs` by default. The naming convention for management log files is:

```
<script_name>_<date>.log
```

The log entry format is:

```
<timestamp>:<utility>:<host>:<user>:[INFO|WARN|FATAL]:<message>
```

The log file for a particular utility execution is appended to its daily log file each time that utility is run.

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4.2.13 Recommended Monitoring and Maintenance Tasks

This section lists monitoring and maintenance activities recommended to ensure high availability and consistent performance of your WarehousePG cluster.

The tables in the following sections suggest activities that a WarehousePG cluster Administrator can perform periodically to ensure that all components of the system are operating optimally. Monitoring activities help you to detect and diagnose problems early. Maintenance activities help you to keep the system up-to-date and avoid deteriorating performance, for example, from bloated system tables or diminishing free disk space.

It is not necessary to implement all of these suggestions in every cluster; use the frequency and severity recommendations as a guide to implement measures according to your service requirements.

Parent topic: Managing a WarehousePG cluster

Database State Monitoring Activities

Table 1. Database State Monitoring Activities

Activity	Procedure	Corrective Actions
List segments that are currently down. If any rows are returned, this should generate a warning or alert. Recommended frequency: run every 5 to 10 minutes Severity: IMPORTANT	Run the following query in the `postgres` database: `SELECT * FROM gp_segment_configuration WHERE status = 'd';`	If the query returns any rows, follow these steps to correct the problem: 1. Verify that the hosts with down segments are responsive. 2. If hosts are OK, check the log files for the primaries and mirrors of the down segments to discover the root cause of the segments going down. 3. If no unexpected errors are found, run the `gprecoverseg` utility to bring the segments back online.
Check for segments that are up and not in sync. If rows are returned, this should generate a warning or alert. Recommended frequency: run every 5 to 10 minutes	Execute the following query in the `postgres` database: `SELECT * FROM gp_segment_configuration WHERE mode = 'n' and status = 'u' and content <> -1;`	If the query returns rows then the segment might be in the process of moving from `Not In Sync` to `Synchronized` mode. Use `gpstate -e` to track progress.
Check for segments that are not operating in their preferred role but are marked as up and `Synchronized`. If any segments are found, the cluster may not be balanced. If any rows are returned this should generate a warning or alert. Recommended frequency: run every 5 to 10 minutes Severity: IMPORTANT	Execute the following query in the `postgres` database: `SELECT * FROM gp_segment_configuration WHERE preferred_role <> role and status = 'u' and mode = 's';`	When the segments are not running in their preferred role, processing might be skewed. Run `gprecoverseg -r` to bring the segments back into their preferred roles.
Run a distributed query to test that it runs on all segments. One row should be returned for each primary segment. Recommended frequency: run every 5 to 10 minutes Severity: CRITICAL	Execute the following query in the `postgres` database: `SELECT gp_segment_id, count(*) FROM gp_dist_random('pg_class') GROUP BY 1;`	If this query fails, there is an issue dispatching to some segments in the cluster. This is a rare event. Check the hosts that are not able to be dispatched to ensure there is no hardware or networking issue.
Test the state of coordinator mirroring on WarehousePG. If the value is not "STREAMING", raise an alert or warning. Recommended frequency: run every 5 to 10 minutes Severity: IMPORTANT	Run the following `psql` command: `psql <dbname> -c 'SELECT pid, state FROM pg_stat_replication;'`	Check the log file from the coordinator and standby coordinator for errors. If there are no unexpected errors and the machines are up, run the `gpinitstandby` utility to bring the standby online.
Perform a basic check to see if the coordinator is up and functioning. Recommended frequency: run every 5 to 10 minutes Severity: CRITICAL	Run the following query in the `postgres` database: `SELECT count(*) FROM gp_segment_configuration;`	If this query fails, the active coordinator may be down. Try to start the database on the original coordinator if the server is up and running. If that fails, try to activate the standby coordinator as coordinator.

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Hardware and Operating System Monitoring

Table 2. Hardware and Operating System Monitoring Activities

Activity	Procedure	Corrective Actions
Check disk space usage on volumes used for WarehousePG data storage and the OS. Recommended frequency: every 5 to 30 minutes Severity: CRITICAL	Set up a disk space check. • Set a threshold to raise an alert when a disk reaches a percentage of capacity. The recommended threshold is 75% full. • It is not recommended to run the system with capacities approaching 100%.	Use `VACUUM` / `VACUUM FULL` on user tables to reclaim space occupied by dead rows.
Check for errors or dropped packets on the network interfaces. Recommended frequency: hourly Severity: IMPORTANT	Set up a network interface checks.	Work with network and OS teams to resolve errors.
Check for RAID errors or degraded RAID performance. Recommended frequency: every 5 minutes Severity: CRITICAL	Set up a RAID check.	• Replace failed disks as soon as possible. • Work with system administration team to resolve other RAID or controller errors as soon as possible.
Check for adequate I/O bandwidth and I/O skew. Recommended frequency: when create a cluster or when hardware issues are suspected.	Run the WarehousePG `gpcheckperf` utility.	The cluster may be under-specified if data transfer rates are not similar to the following: • 2GB per second disk read • 1 GB per second disk write • 10 Gigabit per second network read and write If transfer rates are lower than expected, consult with your data architect regarding performance expectations. If the machines on the cluster display an uneven performance profile, work with the system administration team to fix faulty machines.

Catalog Monitoring

Table 3. Catalog Monitoring Activities

Activity	Procedure	Corrective Actions
Run catalog consistency checks in each database to ensure the catalog on each host in the cluster is consistent and in a good state. You may run this command while the database is up and running. Recommended frequency: weekly Severity: IMPORTANT	Run the WarehousePG `gpcheckcat` utility in each database: `gpcheckcat -O` Note: With the `-O` option, `gpcheckcat` runs just 10 of its usual 15 tests.	Run the repair scripts for any issues identified.
Check for `pg_class` entries that have no corresponding pg_`attribute` entry. Recommended frequency: monthly Severity: IMPORTANT	During a downtime, with no users on the system, run the WarehousePG `gpcheckcat` utility in each database: `gpcheckcat -R pgclass`	Run the repair scripts for any issues identified.
Check for leaked temporary schema and missing schema definition. Recommended frequency: monthly Severity: IMPORTANT	During a downtime, with no users on the system, run the WarehousePG `gpcheckcat` utility in each database: `gpcheckcat -R namespace`	Run the repair scripts for any issues identified.
Check constraints on randomly distributed tables. Recommended frequency: monthly Severity: IMPORTANT	During a downtime, with no users on the system, run the WarehousePG `gpcheckcat` utility in each database: `gpcheckcat -R distribution_policy`	Run the repair scripts for any issues identified.
Check for dependencies on non-existent objects. Recommended frequency: monthly Severity: IMPORTANT	During a downtime, with no users on the system, run the WarehousePG `gpcheckcat` utility in each database: `gpcheckcat -R dependency`	Run the repair scripts for any issues identified.

Data Maintenance

Table 4. Data Maintenance Activities

Activity	Procedure	Corrective Actions

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Activity	Procedure	Corrective Actions
Check for missing statistics on tables.	Check the `gp_stats_missing` view in each database: `SELECT * FROM gp_toolkit.gp_stats_missing;`	Run `ANALYZE` on tables that are missing statistics.
Check for tables that have bloat (dead space) in data files that cannot be recovered by a regular `VACUUM` command. Recommended frequency: weekly or monthly Severity: WARNING	Check the `gp_bloat_diag` view in each database: `SELECT * FROM gp_toolkit.gp_bloat_diag;`	`VACUUM FULL` acquires an `ACCESS EXCLUSIVE` lock on tables. Run `VACUUM FULL` during a time when users and applications do not require access to the tables, such as during a time of low activity, or during a maintenance window.

Database Maintenance

Table 5. Database Maintenance Activities

Activity	Procedure	Corrective Actions
Reclaim space occupied by deleted rows in the heap tables so that the space they occupy can be reused. Recommended frequency: daily Severity: CRITICAL	Vacuum user tables: `VACUUM <table>;`	Vacuum updated tables regularly to prevent bloating.
Update table statistics. Recommended frequency: after loading data and before executing queries Severity: CRITICAL	Analyze user tables. You can use the `analyzedb` management utility: `analyzedb -d <database> -a`	Analyze updated tables regularly so that the optimizer can produce efficient query execution plans.
Backup the database data. Recommended frequency: daily, or as required by your backup plan Severity: CRITICAL	Run the `gpbackup` utility to create a backup of the coordinator and segment databases in parallel.	Best practice is to have a current backup ready in case the database must be restored.

Vacuum, reindex, and analyze system catalogs to maintain an efficient catalog.
Recommended frequency: weekly, or more often if database objects are created and dropped frequently
	1. `VACUUM` the system tables in each database.
	2. Run `REINDEX SYSTEM` in each database, or use the `reindexdb` command-line utility with the `-s` option:
	`reindexdb -s <database>`
	3. `ANALYZE` each of the system tables:
	`analyzedb -s pg_catalog -d <database>`
		The optimizer retrieves information from the system tables to create query plans. If system tables and indexes are allowed to become bloated over time, scanning the system tables increases query execution time. It is important to run `ANALYZE` after reindexing, because `REINDEX` leaves indexes with no statistics.

Patching and Upgrading

Table 6. Patch and Upgrade Activities

Activity	Procedure	Corrective Actions
Ensure any bug fixes or enhancements are applied to the kernel. Recommended frequency: at least every 6 months Severity: IMPORTANT	Follow the vendor's instructions to update the Linux kernel.	Keep the kernel current to include bug fixes and security fixes, and to avoid difficult future upgrades.
Install WarehousePG minor releases, for example 5.0.*x*. Recommended frequency: quarterly Severity: IMPORTANT	Follow upgrade instructions in the WarehousePG *Release Notes*. Always upgrade to the latest in the series.	Keep the WarehousePG software current to incorporate bug fixes, performance enhancements, and feature enhancements into your WarehousePG cluster.

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4.3 Managing WarehousePG Access

Securing WarehousePG includes protecting access to the database through network configuration, database user authentication, and encryption.

- Configuring Client Authentication
  This topic explains how to configure client connections and authentication for WarehousePG.
- Managing Roles and Privileges
  The WarehousePG authorization mechanism stores roles and permissions to access database objects in the database and is administered using SQL statements or command-line utilities.
- About Configuring Row-Level Security Policies
  This topic describes how to configure row-level security policies for WarehousePG tables.

Parent topic: WarehousePG Administrator Guide

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4.3.1 Configuring Client Authentication

This topic explains how to configure client connections and authentication for WarehousePG.

When a WarehousePG cluster is first initialized, the system contains one predefined *superuser* role. This role will have the same name as the operating system user who initialized the WarehousePG cluster. This role is referred to as `gpadmin`. By default, the system is configured to only allow local connections to the database from the `gpadmin` role. If you want to allow any other roles to connect, or if you want to allow connections from remote hosts, you have to configure WarehousePG to allow such connections. This section explains how to configure client connections and authentication to WarehousePG.

- **Using LDAP Authentication with TLS/SSL**
  You can control access to WarehousePG with an LDAP server and, optionally, secure the connection with encryption by adding parameters to pg_hba.conf file entries.
- **Using Kerberos Authentication**
  You can control access to WarehousePG with a Kerberos authentication server.
- **Configuring Kerberos for Linux Clients**
  You can configure Linux client applications to connect to a WarehousePG cluster that is configured to authenticate with Kerberos.
- **Configuring Kerberos For Windows Clients**
  You can configure Microsoft Windows client applications to connect to a WarehousePG cluster that is configured to authenticate with Kerberos.

Parent topic: Managing WarehousePG Access

Allowing Connections to WarehousePG

Client access and authentication is controlled by the standard PostgreSQL host-based authentication file, pg_hba.conf. For detailed information about this file, see The pg_hba.conf File in the PostgreSQL documentation.

In WarehousePG, the pg_hba.conf file of the coordinator instance controls client access and authentication to your WarehousePG cluster. The WarehousePG segments also have pg_hba.conf files, but these are already correctly configured to allow only client connections from the coordinator host. The segments never accept outside client connections, so there is no need to alter the `pg_hba.conf` file on segments.

The general format of the pg_hba.conf file is a set of records, one per line. WarehousePG ignores blank lines and any text after the `#` comment character. A record consists of a number of fields that are separated by spaces or tabs. Fields can contain white space if the field value is quoted. Records cannot be continued across lines. Each remote client access record has the following format:

```
host   database   role   address   authentication-method
```

Each UNIX-domain socket access record is in this format:

```
local   database   role   authentication-method
```

The following table describes the meaning of each field in the `pg_hba.conf` file:

Field	Description
local	Matches connection attempts using UNIX-domain sockets. Without a record of this type, UNIX-domain socket connections are disallowed.
host	Matches connection attempts made using TCP/IP. Remote TCP/IP connections will not be possible unless the server is started with an appropriate value for the `listen_addresses` server configuration parameter.
hostssl	Matches connection attempts made using TCP/IP, but only when the connection is made with SSL encryption. SSL must be enabled at server start time by setting the `ssl` server configuration parameter.
hostnossl	Matches connection attempts made over TCP/IP that do not use SSL.
database	Specifies which database names this record matches. The value `all` specifies that it matches all databases. Multiple database names can be supplied by separating them with commas. A separate file containing database names can be specified by preceding the file name with a `@`.
role	Specifies which database role names this record matches. The value `all` specifies that it matches all roles. If the specified role is a group and you want all members of that group to be included, precede the role name with a `+`. Multiple role names can be supplied by separating them with commas. A separate file containing role names can be specified by preceding the file name with a `@`.
address	Specifies the client machine addresses that this record matches. This field can contain an IP address, an IP address range, or a host name. An IP address range is specified using standard numeric notation for the range's starting address, then a slash (`/`) and a CIDR mask length. The mask length indicates the number of high-order bits of the client IP address that must match. Bits to the right of this should be zero in the given IP address. There must not be any white space between the IP address, the `/`, and the CIDR mask length. Typical examples of an IPv4 address range specified this way are `172.20.143.89/32` for a single host, or `172.20.143.0/24` for a small network, or `10.6.0.0/16` for a larger one. An IPv6 address range might look like `::1/128` for a single host (in this case the IPv6 loopback address) or `fe80::7a31:c1ff:0000:0000/96` for a small network. `0.0.0.0/0` represents all IPv4 addresses, and `::0/0` represents all IPv6 addresses. To specify a single host, use a mask length of 32 for IPv4 or 128 for IPv6. In a network address, do not omit trailing zeroes. An entry given in IPv4 format will match only IPv4 connections, and an entry given in IPv6 format will match only IPv6 connections, even if the represented address is in the IPv4-in-IPv6 range. **Note:** Entries in IPv6 format will be rejected if the host system C library does not have support for IPv6 addresses. If a host name is specified (an address that is not an IP address or IP range is treated as a host name), that name is compared with the result of a reverse name resolution of the client IP address (for example, reverse DNS lookup, if DNS is used). Host name comparisons are case insensitive. If there is a match, then a forward name resolution (for example, forward DNS lookup) is performed on the host name to check whether any of the addresses it resolves to are equal to the client IP address. If both directions match, then the entry is considered to match. Some host name databases allow associating an IP address with multiple host names, but the operating system only returns one host name when asked to resolve an IP address. The host name that is used in `pg_hba.conf` must be the one that the address-to-name resolution of the client IP address returns, otherwise the line will not be considered a match. When host names are specified in `pg_hba.conf`, you should ensure that name resolution is reasonably fast. It can be of advantage to set up a local name resolution cache such as `nscd`. Also, you can enable the server configuration parameter `log_hostname` to see the client host name instead of the IP address in the log.
IP-address / IP-mask	These fields can be used as an alternative to the CIDR address notation. Instead of specifying the mask length, the actual mask is specified in a separate column. For example, `255.0.0.0` represents an IPv4 CIDR mask length of 8, and `255.255.255.255` represents a CIDR mask length of 32.
authentication-method	Specifies the authentication method to use when connecting. WarehousePG supports the authentication methods supported by PostgreSQL 12.

Caution: For a more secure system, consider removing records for remote connections that use trust authentication from the `pg_hba.conf` file. Trust authentication grants any user who can connect to the server access to the database using any role they specify. You can safely replace trust authentication with ident authentication for local UNIX-socket connections. You can also use ident authentication for local and remote TCP clients, but the client host must be running an ident service and you must trust the integrity of that machine.

Editing the pg_hba.conf File

Initially, the `pg_hba.conf` file is set up with generous permissions for the gpadmin user and no database access for other WarehousePG roles. You will need to edit the `pg_hba.conf` file to enable users' access to databases and to secure the gpadmin user. Consider removing entries that have trust authentication, since they allow anyone with access to the server to connect with any role they choose. For local (UNIX socket) connections, use ident authentication, which requires the operating system user to match the role specified. For local and remote TCP connections, ident authentication requires the client's host to run an indent service. You can install an ident service on the coordinator host and then use ident authentication for local TCP connections, for example `127.0.0.1/28`. Using ident authentication for remote TCP connections is less secure because it requires you to trust the integrity of the ident service on the client's host.

This example shows how to edit the pg_hba.conf file of the coordinator to allow remote client access to all databases from all roles using encrypted password authentication.

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Editing pg_hba.conf

1. Open the file $COORDINATOR_DATA_DIRECTORY/pg_hba.conf in a text editor.

2. Add a line to the file for each type of connection you want to allow. Records are read sequentially, so the order of the records is significant. Typically, earlier records will have tight connection match parameters and weaker authentication methods, while later records will have looser match parameters and stronger authentication methods. For example:

```
# allow the gpadmin user local access to all databases
# using ident authentication
local   all   gpadmin   ident         sameuser
host    all   gpadmin   127.0.0.1/32  ident
host    all   gpadmin   ::1/128       ident
# allow the 'dba' role access to any database from any
# host with IP address 192.168.x.x and use md5 encrypted
# passwords to authenticate the user
# Note that to use SHA-256 encryption, replace md5 with
# password in the line below
host    all   dba   192.168.0.0/32  md5
# allow all roles access to any database from any
# host and use ldap to authenticate the user. WarehousePG role
# names must match the LDAP common name.
host    all   all   192.168.0.0/32  ldap ldapserver=usldap1 ldapport=1389 ldapprefix="cn=" ldapsuffix=",ou=People,dc=company,dc=com"
```

3. Save and close the file.

4. Reload the pg_hba.conf configuration file for your changes to take effect:

```
$ gpstop -u
```

> **Note** Note that you can also control database access by setting object privileges as described in Managing Object Privileges. The pg_hba.conf file just controls who can initiate a database session and how those connections are authenticated.

Limiting Concurrent Connections

WarehousePG allocates some resources on a per-connection basis, so setting the maximum number of connections allowed is recommended.

To limit the number of active concurrent sessions to your WarehousePG cluster, you can configure the `max_connections` server configuration parameter. This is a *local* parameter, meaning that you must set it in the `postgresql.conf` file of the coordinator, the standby coordinator, and each segment instance (primary and mirror). The recommended value of `max_connections` on segments is 5-10 times the value on the coordinator.

When you set `max_connections`, you must also set the dependent parameter `max_prepared_transactions`. This value must be at least as large as the value of `max_connections` on the coordinator, and segment instances should be set to the same value as the coordinator.

For example:

- In `$COORDINATOR_DATA_DIRECTORY/postgresql.conf` (including standby coordinator):

```
max_connections=100
max_prepared_transactions=100
```

- In `SEGMENT_DATA_DIRECTORY/postgresql.conf` for all segment instances:

```
max_connections=500
max_prepared_transactions=100
```

The following steps set the parameter values with the WarehousePG utility `gpconfig`.

For information about `gpconfig`, see the *WarehousePG Utility Guide*.

To change the number of allowed connections

1. Log into the WarehousePG coordinator host as the WarehousePG administrator and source the file `$GPHOME/greenplum_path.sh`.

2. Set the value of the `max_connections` parameter. This `gpconfig` command sets the value on the segments to 1000 and the value on the coordinator to 200.

```
$ gpconfig -c max_connections -v 1000 -m 200
```

   The value on the segments must be greater than the value on the coordinator. The recommended value of `max_connections` on segments is 5-10 times the value on the coordinator.

3. Set the value of the `max_prepared_transactions` parameter. This `gpconfig` command sets the value to 200 on the coordinator and all segments.

```
$ gpconfig -c max_prepared_transactions -v 200
```

   The value of `max_prepared_transactions` must be greater than or equal to `max_connections` on the coordinator.

4. Stop and restart your WarehousePG cluster.

```
$ gpstop -r
```

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5. You can check the value of parameters on the coordinator and segments with the `gpconfig -s` option. This `gpconfig` command displays the values of the `max_connections` parameter.

```
$ gpconfig -s max_connections
```

> **Note** Raising the values of these parameters may cause WarehousePG to request more shared memory. To mitigate this effect, consider decreasing other memory-related parameters such as `gp_cached_segworkers_threshold`.

Encrypting Client/Server Connections

Enable SSL for client connections to WarehousePG to encrypt the data passed over the network between the client and the database.

WarehousePG has native support for SSL connections between the client and the coordinator server. SSL connections prevent third parties from snooping on the packets, and also prevent man-in-the-middle attacks. SSL should be used whenever the client connection goes through an insecure link, and must be used whenever client certificate authentication is used.

Enabling WarehousePG in SSL mode requires the following items.

- OpenSSL installed on both the client and the coordinator server hosts (coordinator and standby coordinator).
- The SSL files server.key (server private key) and server.crt (server certificate) should be correctly generated for the coordinator host and standby coordinator host.
    - The private key should not be protected with a passphrase. The server does not prompt for a passphrase for the private key, and WarehousePG start up fails with an error if one is required.
    - On a production system, there should be a key and certificate pair for the coordinator host and a pair for the standby coordinator host with a subject CN (Common Name) for the coordinator host and standby coordinator host. A self-signed certificate can be used for testing, but a certificate signed by a certificate authority (CA) should be used in production, so the client can verify the identity of the server. Either a global or local CA can be used. If all the clients are local to the organization, a local CA is recommended.
- Ensure that WarehousePG can access server.key and server.crt, and any additional authentication files such as `root.crt` (for trusted certificate authorities). When starting in SSL mode, the WarehousePG coordinator looks for server.key and server.crt. As the default, WarehousePG does not start if the files are not in the coordinator data directory (`$COORDINATOR_DATA_DIRECTORY`). Also, if you use other SSL authentication files such as `root.crt` (trusted certificate authorities), the files must be on the coordinator host.

  If WarehousePG coordinator mirroring is enabled with SSL client authentication, SSL authentication files must be on both the coordinator host and standby coordinator host and *should not be placed* in the default directory `$COORDINATOR_DATA_DIRECTORY`. When coordinator mirroring is enabled, an `initstandby` operation copies the contents of the `$COORDINATOR_DATA_DIRECTORY` from the coordinator to the standby coordinator and the incorrect SSL key, and cert files (the coordinator files, and not the standby coordinator files) will prevent standby coordinator start up.

  You can specify a different directory for the location of the SSL server files with the `postgresql.conf` parameters `sslcert`, `sslkey`, `sslrootcert`, and `sslcrl`. For more information about the parameters, see SSL Client Authentication in the *Security Configuration Guide*.

WarehousePG can be started with SSL enabled by setting the server configuration parameter `ssl=on` in the `postgresql.conf` file on the coordinator and standby coordinator hosts. This `gpconfig` command sets the parameter:

```
gpconfig -c ssl -m on -v off
```

Setting the parameter requires a server restart. This command restarts the system: `gpstop -ra`.

Creating a Self-signed Certificate without a Passphrase for Testing Only

To create a quick self-signed certificate for the server for testing, use the following OpenSSL command:

```
# openssl req -new -text -out server.req
```

Enter the information requested by the prompts. Be sure to enter the local host name as *Common Name*. The challenge password can be left blank.

The program will generate a key that is passphrase protected, and does not accept a passphrase that is less than four characters long.

To use this certificate with WarehousePG, remove the passphrase with the following commands:

```
# openssl rsa -in privkey.pem -out server.key
# rm privkey.pem
```

Enter the old passphrase when prompted to unlock the existing key.

Then, enter the following command to turn the certificate into a self-signed certificate and to copy the key and certificate to a location where the server will look for them.

```
# openssl req -x509 -in server.req -text -key server.key -out server.crt
```

Finally, change the permissions on the key with the following command. The server will reject the file if the permissions are less restrictive than these.

```
# chmod og-rwx server.key
```

For more details on how to create your server private key and certificate, refer to theOpenSSL documentation.

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4.3.1.1 Using LDAP Authentication with TLS/SSL

You can control access to WarehousePG with an LDAP server and, optionally, secure the connection with encryption by adding parameters to pg_hba.conf file entries.

WarehousePG supports LDAP authentication with the TLS/SSL protocol to encrypt communication with an LDAP server:

- LDAP authentication with STARTTLS and TLS protocol – STARTTLS starts with a clear text connection (no encryption) and upgrades it to a secure connection (with encryption).
- LDAP authentication with a secure connection and TLS/SSL (LDAPS) – WarehousePG uses the TLS or SSL protocol based on the protocol that is used by the LDAP server.

If no protocol is specified, WarehousePG communicates with the LDAP server with a clear text connection.

To use LDAP authentication, the WarehousePG coordinator host must be configured as an LDAP client. See your LDAP documentation for information about configuring LDAP clients.

Enabling LDAP Authentication with STARTTLS and TLS

To enable STARTTLS with the TLS protocol, in the pg_hba.conf file, add an `ldap` line and specify the `ldaptls` parameter with the value `1`. The default port is 389. In this example, the authentication method parameters include the `ldaptls` parameter.

```
ldap ldapserver=myldap.com ldaptls=1 ldapprefix="uid=" ldapsuffix=",ou=People,dc=example,dc=com"
```

Specify a non-default port with the `ldapport` parameter. In this example, the authentication method includes the `ldaptls` parameter and the `ldapport` parameter to specify the port 500.

```
ldap ldapserver=myldap.com ldaptls=1 ldapport=500 ldapprefix="uid=" ldapsuffix=",ou=People,dc=example,dc=com"
```

Enabling LDAP Authentication with a Secure Connection and TLS/SSL

To enable a secure connection with TLS/SSL, add `ldaps://` as the prefix to the LDAP server name specified in the `ldapserver` parameter. The default port is 636.

This example `ldapserver` parameter specifies a secure connection and the TLS/SSL protocol for the LDAP server `myldap.com`.

```
ldapserver=ldaps://myldap.com
```

To specify a non-default port, add a colon (:) and the port number after the LDAP server name. This example `ldapserver` parameter includes the `ldaps://` prefix and the non-default port 550.

```
ldapserver=ldaps://myldap.com:550
```

Configuring Authentication with a System-wide OpenLDAP System

If you have a system-wide OpenLDAP system and logins are configured to use LDAP with TLS or SSL in the pg_hba.conf file, logins may fail with the following message:

```
could not start LDAP TLS session: error code '-11'
```

To use an existing OpenLDAP system for authentication, WarehousePG must be set up to use the LDAP server's CA certificate to validate user certificates. Follow these steps on both the coordinator and standby hosts to configure WarehousePG:

1. Copy the base64-encoded root CA chain file from the Active Directory or LDAP server to the WarehousePG coordinator and standby coordinator hosts. This example uses the directory `/etc/pki/tls/certs`.

2. Change to the directory where you copied the CA certificate file and, as the root user, generate the hash for OpenLDAP:

   ```
   # cd /etc/pki/tls/certs
   # openssl x509 -noout -hash -in <ca-certificate-file>
   # ln -s <ca-certificate-file> <ca-certificate-file>.0
   ```

3. Configure an OpenLDAP configuration file for WarehousePG with the CA certificate directory and certificate file specified.

   As the root user, edit the OpenLDAP configuration file `/etc/openldap/ldap.conf`:

   ```
   SASL_NOCANON on
    URI ldaps://ldapA.example.priv ldaps://ldapB.example.priv ldaps://ldapC.example.priv
    BASE dc=example,dc=priv
    TLS_CACERTDIR /etc/pki/tls/certs
    TLS_CACERT /etc/pki/tls/certs/<ca-certificate-file>
   ```

   > **Note** For certificate validation to succeed, the hostname in the certificate must match a hostname in the URI property. Otherwise, you must also add `TLS_REQCERT allow` to the file.

4. As the gpadmin user, edit `/usr/edb/whpg7/greenplum_path.sh` and add the following line.

   ```
   export LDAPCONF=/etc/openldap/ldap.conf
   ```

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Notes

WarehousePG logs an error if the following are specified in an pg_hba.conf file entry:

- If both the `ldaps://` prefix and the `ldaptls=1` parameter are specified.
- If both the `ldaps://` prefix and the `ldapport` parameter are specified.

Enabling encrypted communication for LDAP authentication only encrypts the communication between WarehousePG and the LDAP server.

See Encrypting Client/Server Connections for information about encrypting client connections.

Examples

These are example entries from an pg_hba.conf file.

This example specifies LDAP authentication with no encryption between WarehousePG and the LDAP server.

```
host all plainuser 0.0.0.0/0 ldap ldapserver=myldap.com ldapprefix="uid=" ldapsuffix=",ou=People,dc=example,dc=com"
```

This example specifies LDAP authentication with the STARTTLS and TLS protocol between WarehousePG and the LDAP server.

```
host all tlsuser 0.0.0.0/0 ldap ldapserver=myldap.com ldaptls=1 ldapprefix="uid=" ldapsuffix=",ou=People,dc=example,dc=com"
```

This example specifies LDAP authentication with a secure connection and TLS/SSL protocol between WarehousePG and the LDAP server.

```
host all ldapsuser 0.0.0.0/0 ldap ldapserver=myldap.com ldapscheme=ldaps ldapprefix="uid=" ldapsuffix=",ou=People,dc=example,dc=com"
```

This example also specifies LDAP authentication with a secure connection and TLS/SSL protocol between WarehousePG and the LDAP server, using an alternative syntax.

```
host all ldapsuser 0.0.0.0/0 ldap ldapurl=ldaps://myldap.com ldapprefix="uid=" ldapsuffix=",ou=People,dc=example,dc=com"
```

Parent topic: Configuring Client Authentication

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4.3.1.2 Using Kerberos Authentication

You can control access to WarehousePG with a Kerberos authentication server.

WarehousePG supports the Generic Security Service Application Program Interface (GSSAPI) with Kerberos authentication. GSSAPI provides automatic authentication (single sign-on) for systems that support it. You specify the WarehousePG users (roles) that require Kerberos authentication in the WarehousePG configuration file pg_hba.conf. The login fails if Kerberos authentication is not available when a role attempts to log in to WarehousePG.

Kerberos provides a secure, encrypted authentication service. It does not encrypt data exchanged between the client and database and provides no authorization services. To encrypt data exchanged over the network, you must use an SSL connection. To manage authorization for access to WarehousePGs and objects such as schemas and tables, you use settings in the pg_hba.conf file and privileges given to WarehousePG users and roles within the database. For information about managing authorization privileges, see Managing Roles and Privileges.

For more information about Kerberos, see http://web.mit.edu/kerberos/.

Prerequisites

Before configuring Kerberos authentication for WarehousePG, ensure that:

- You can identify the KDC server you use for Kerberos authentication and the Kerberos realm for your WarehousePG cluster. If you have not yet configured your MIT Kerberos KDC server, see Installing and Configuring a Kerberos KDC Server for example instructions.
- System time on the Kerberos Key Distribution Center (KDC) server and WarehousePG coordinator is synchronized. (For example, install the `ntp` package on both servers.)
- Network connectivity exists between the KDC server and the WarehousePG coordinator host.
- Java 1.7.0_17 or later is installed on all WarehousePG hosts. Java 1.7.0_17 is required to use Kerberos-authenticated JDBC on Red Hat Enterprise Linux 6.x or 7.x.

Procedure

Following are the tasks to complete to set up Kerberos authentication for WarehousePG.

- Creating WarehousePG Principals in the KDC Database
- Installing the Kerberos Client on the Coordinator Host
- Configuring WarehousePG to use Kerberos Authentication
- Mapping Kerberos Principals to WarehousePG Roles
- Configuring JDBC Kerberos Authentication for WarehousePG
- Configuring Kerberos for Linux Clients
- Configuring Kerberos For Windows Clients

Parent topic: Configuring Client Authentication

Creating WarehousePG Principals in the KDC Database

Create a service principal for the WarehousePG service and a Kerberos admin principal that allows managing the KDC database as the gpadmin user.

1. Log in to the Kerberos KDC server as the root user.

   ```
   $ ssh root@<kdc-server>
   ```

2. Create a principal for the WarehousePG service.

   ```
   # kadmin.local -q "addprinc -randkey servicename/hostname@realm"
   ```

   The `-randkey` option prevents the command from prompting for a password.

   The `servicename` part of the principal is ordinarily `postgres`, but you may specify a different value via the `libpq`'s configuration parameter `krbsrvname`.

   The `hostname` part of the principal name must match the output of the `hostname` command on the WarehousePG coordinator host. If the `hostname` command shows the fully qualified domain name (FQDN), use it in the principal name, for example `postgres/cdw.example.com@GPDB.KRB`.

   The `realm` part of the principal name is the Kerberos realm name. For example, `GPDB.KRB`.

3. Create a principal for the gpadmin/admin role.

   ```
   # kadmin.local -q "addprinc gpadmin/admin@realm"
   ```

   This principal allows you to manage the KDC database when you are logged in as gpadmin. Make sure that the Kerberos `kadm.acl` configuration file contains an ACL to grant permissions to this principal. For example, this ACL grants all permissions to any admin user in the `GPDB.KRB` realm.

   ```
   */admin@GPDB.KRB *
   ```

4. Create a keytab file with `kadmin.local`. The following example creates a keytab file `gpdb-kerberos.keytab` in the current directory with authentication information for the WarehousePG service principal and the gpadmin/admin principal.

   ```
   # kadmin.local -q "ktadd -k gpdb-kerberos.keytab postgres/cdw@GPDB.KRB gpadmin/admin@GPDB.KRB"
   ```

5. Copy the keytab file to the coordinator host.

   ```
   # scp gpdb-kerberos.keytab gpadmin@cdw:~
   ```

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Installing the Kerberos Client on the Coordinator Host

Install the Kerberos client utilities and libraries on the WarehousePG coordinator.

1. Install the Kerberos packages on the WarehousePG coordinator.

```
$ sudo yum install krb5-libs krb5-workstation
```

2. Copy the `/etc/krb5.conf` file from the KDC server to `/etc/krb5.conf` on the WarehousePG Coordinator host.

Configuring WarehousePG to use Kerberos Authentication

Configure WarehousePG to use Kerberos.

1. Log in to the WarehousePG coordinator host as the gpadmin user.

```
$ ssh gpadmin@<coordinator>
$ source /usr/edb/whpg7/greenplum_path.sh
```

2. Set the ownership and permissions of the keytab file you copied from the KDC server.

```
$ chown gpadmin:gpadmin /home/gpadmin/gpdb-kerberos.keytab
$ chmod 400 /home/gpadmin/gpdb-kerberos.keytab
```

3. Configure the location of the keytab file by setting the WarehousePG `krb_server_keyfile` server configuration parameter. This `gpconfig` command specifies the folder /home/gpadmin as the location of the keytab file gpdb-kerberos.keytab.

```
$ gpconfig -c krb_server_keyfile -v  '/home/gpadmin/gpdb-kerberos.keytab'
```

4. Modify the WarehousePG file `pg_hba.conf` to enable Kerberos support. For example, adding the following line to `pg_hba.conf` adds GSSAPI and Kerberos authentication support for connection requests from all users and hosts on the same network to all WarehousePG databases.

```
host all all 0.0.0.0/0 gss include_realm=0 krb_realm=GPDB.KRB
```

   Setting the `krb_realm` option to a realm name ensures that only users from that realm can successfully authenticate with Kerberos. Setting the `include_realm` option to `0` excludes the realm name from the authenticated user name. For information about the `pg_hba.conf` file, see The pg_hba.conf file in the PostgreSQL documentation.

5. Restart WarehousePG after updating the `krb_server_keyfile` parameter and the `pg_hba.conf` file.

```
$ gpstop -ar
```

6. Create the gpadmin/admin WarehousePG superuser role.

```
$ createuser gpadmin/admin --superuser
```

   The Kerberos keys for this database role are in the keyfile you copied from the KDC server.

7. Create a ticket using `kinit` and show the tickets in the Kerberos ticket cache with `klist`.

```
$ LD_LIBRARY_PATH= kinit -k -t /home/gpadmin/gpdb-kerberos.keytab gpadmin/admin@GPDB.KRB
$ LD_LIBRARY_PATH= klist
Ticket cache: FILE:/tmp/krb5cc_1000
Default principal: gpadmin/admin@GPDB.KRB

Valid starting       Expires              Service principal
06/13/2018 17:37:35  06/14/2018 17:37:35  krbtgt/GPDB.KRB@GPDB.KRB
```

> **Note** When you set up the WarehousePG environment by sourcing the `greenplum-db_path.sh` script, the `LD_LIBRARY_PATH` environment variable is set to include the WarehousePG `lib` directory, which includes Kerberos libraries. This may cause Kerberos utility commands such as `kinit` and `klist` to fail due to version conflicts. The solution is to run Kerberos utilities before you source the `greenplum-db_path.sh` file or temporarily unset the `LD_LIBRARY_PATH` variable when you run Kerberos utilities, as shown in the example.

8. As a test, log in to the postgres database with the `gpadmin/admin` role:

```
$ psql -U "gpadmin/admin" -h cdw postgres
psql (9.4.20)
Type "help" for help.

postgres=# select current_user;
 current_user
---------------
 gpadmin/admin
(1 row)
```

> **Note** When you start `psql` on the coordinator host, you must include the `-h <coordinator-hostname>` option to force a TCP connection because Kerberos authentication does not work with local connections.

If a Kerberos principal is not a WarehousePG user, a message similar to the following is displayed from the `psql` command line when the user attempts to log in to the database:

```
psql: krb5_sendauth: Bad response
```

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The principal must be added as a WarehousePG user.

Mapping Kerberos Principals to WarehousePG Roles

To connect to a WarehousePG cluster with Kerberos authentication enabled, a user first requests a ticket-granting ticket from the KDC server using the `kinit` utility with a password or a keytab file provided by the Kerberos admin. When the user then connects to the Kerberos-enabled WarehousePG cluster, the user's Kerberos principle name will be the WarehousePG role name, subject to transformations specified in the options field of the `gss` entry in the WarehousePG `pg_hba.conf` file:

- If the `krb_realm=<realm>` option is present, WarehousePG only accepts Kerberos principals who are members pf the specified realm.
- If the `include_realm=0` option is specified, the WarehousePG role name is the Kerberos principal name without the Kerberos realm. If the `include_realm=1` option is instead specified, the Kerberos realm is not stripped from the WarehousePG rolename. The role must have been created with the WarehousePG `CREATE ROLE` command.
- If the `map=<map-name>` option is specified, the Kerberos principal name is compared to entries labeled with the specified `<map-name>` in the `$COORDINATOR_DATA_DIRECTORY/pg_ident.conf` file and replaced with the WarehousePG role name specified in the first matching entry.

A user name map is defined in the `$COORDINATOR_DATA_DIRECTORY/pg_ident.conf` configuration file. This example defines a map named `mymap` with two entries.

```
# MAPNAME    SYSTEM-USERNAME         GP-USERNAME
mymap        /^admin@GPDB.KRB$       gpadmin
mymap        /^(.*)_gp)@GPDB.KRB$    \1
```

The map name is specified in the `pg_hba.conf` Kerberos entry in the options field:

```
host all all 0.0.0.0/0 gss include_realm=0 krb_realm=GPDB.KRB map=mymap
```

The first map entry matches the Kerberos principal admin@GPDB.KRB and replaces it with the WarehousePG gpadmin role name. The second entry uses a wildcard to match any Kerberos principal in the GPDB-KRB realm with a name ending with the characters `_gp` and replaces it with the initial portion of the principal name. WarehousePG applies the first matching map entry in the `pg_ident.conf` file, so the order of entries is significant.

For more information about using username maps see Username maps in the PostgreSQL documentation.

Configuring JDBC Kerberos Authentication for WarehousePG

Enable Kerberos-authenticated JDBC access to WarehousePG.

You can configure WarehousePG to use Kerberos to run user-defined Java functions.

1. Ensure that Kerberos is installed and configured on the WarehousePG coordinator. See Installing the Kerberos Client on the Coordinator Host.

2. Create the file .java.login.config in the folder `/home/gpadmin` and add the following text to the file:

   ```
   pgjdbc {
     com.sun.security.auth.module.Krb5LoginModule required
     doNotPrompt=true
     useTicketCache=true
     debug=true
     client=true;
   };
   ```

3. Create a Java application that connects to WarehousePG using Kerberos authentication. The following example database connection URL uses a PostgreSQL JDBC driver and specifies parameters for Kerberos authentication:

   ```
   jdbc:postgresql://cdw:5432/mytest?kerberosServerName=postgres
   &jaasApplicationName=pgjdbc&user=gpadmin/gpdb-kdc
   ```

   The parameter names and values specified depend on how the Java application performs Kerberos authentication.

4. Test the Kerberos login by running a sample Java application from WarehousePG.

Installing and Configuring a Kerberos KDC Server

Steps to set up a Kerberos Key Distribution Center (KDC) server on a Red Hat Enterprise Linux host for use with WarehousePG.

If you do not already have a KDC, follow these steps to install and configure a KDC server on a Red Hat Enterprise Linux host with a `GPDB.KRB` realm. The host name of the KDC server in this example is gpdb-kdc.

1. Install the Kerberos server and client packages:

   ```
   $ sudo yum install krb5-libs krb5-server krb5-workstation
   ```

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2. Edit the /etc/krb5.conf configuration file. The following example shows a Kerberos server configured with a default `GPDB.KRB` realm.

```
[logging]
 default = FILE:/var/log/krb5libs.log
 kdc = FILE:/var/log/krb5kdc.log
 admin_server = FILE:/var/log/kadmind.log

[libdefaults]
 default_realm = GPDB.KRB
 dns_lookup_realm = false
 dns_lookup_kdc = false
 ticket_lifetime = 24h
 renew_lifetime = 7d
 forwardable = true
 default_tgs_enctypes = aes128-cts des3-hmac-sha1 des-cbc-crc des-cbc-md5
 default_tkt_enctypes = aes128-cts des3-hmac-sha1 des-cbc-crc des-cbc-md5
 permitted_enctypes = aes128-cts des3-hmac-sha1 des-cbc-crc des-cbc-md5

[realms]
 GPDB.KRB = {
  kdc = gpdb-kdc:88
  admin_server = gpdb-kdc:749
  default_domain = gpdb.krb
 }

[domain_realm]
 .gpdb.krb = GPDB.KRB
 gpdb.krb = GPDB.KRB

[appdefaults]
 pam = {
    debug = false
    ticket_lifetime = 36000
    renew_lifetime = 36000
    forwardable = true
    krb4_convert = false
 }
```

   The `kdc` and `admin_server` keys in the `[realms]` section specify the host (`gpdb-kdc`) and port where the Kerberos server is running. IP numbers can be used in place of host names.

   If your Kerberos server manages authentication for other realms, you would instead add the `GPDB.KRB` realm in the `[realms]` and `[domain_realm]` section of the `kdc.conf` file. See the Kerberos documentation for information about the `kdc.conf` file.

3. To create the Kerberos database, run the `kdb5_util`.

```
# kdb5_util create -s
```

   The `kdb5_util` create command creates the database to store keys for the Kerberos realms that are managed by this KDC server. The -s option creates a stash file. Without the stash file, every time the KDC server starts it requests a password.

4. Add an administrative user to the KDC database with the `kadmin.local` utility. Because it does not itself depend on Kerberos authentication, the `kadmin.local` utility allows you to add an initial administrative user to the local Kerberos server. To add the user `gpadmin` as an administrative user to the KDC database, run the following command:

```
# kadmin.local -q "addprinc gpadmin/admin"
```

   Most users do not need administrative access to the Kerberos server. They can use `kadmin` to manage their own principals (for example, to change their own password). For information about `kadmin`, see the Kerberos documentation.

5. If needed, edit the /var/kerberos/krb5kdc/kadm5.acl file to grant the appropriate permissions to `gpadmin`.

6. Start the Kerberos daemons:

```
# /sbin/service krb5kdc start#
/sbin/service kadmin start
```

7. To start Kerberos automatically upon restart:

```
# /sbin/chkconfig krb5kdc on
# /sbin/chkconfig kadmin on
```

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4.3.1.3 Configuring Kerberos for Linux Clients

You can configure Linux client applications to connect to a WarehousePG cluster that is configured to authenticate with Kerberos.

If your JDBC application on Red Hat Enterprise Linux uses Kerberos authentication when it connects to your WarehousePG, your client system must be configured to use Kerberos authentication. If you are not using Kerberos authentication to connect to a WarehousePG, Kerberos is not needed on your client system.

- Requirements
- Setting Up Client System with Kerberos Authentication
- Running a Java Application

For information about enabling Kerberos authentication with WarehousePG, see the chapter "Setting Up Kerberos Authentication" in the *WarehousePG Administrator Guide*.

Parent topic: Configuring Client Authentication

Requirements

The following are requirements to connect to a WarehousePG that is enabled with Kerberos authentication from a client system with a JDBC application.

- Prerequisites
- Required Software on the Client Machine

Prerequisites

- Kerberos must be installed and configured on the WarehousePG coordinator host.

  > **Important** WarehousePG must be configured so that a remote user can connect to WarehousePG with Kerberos authentication. Authorization to access WarehousePG is controlled by the `pg_hba.conf` file. For details, see "Editing the pg_hba.conf File" in the *WarehousePG Administration Guide*, and also see the *WarehousePG Security Configuration Guide*.

- The client system requires the Kerberos configuration file `krb5.conf` from the WarehousePG coordinator.

- The client system requires a Kerberos keytab file that contains the authentication credentials for the WarehousePG user that is used to log into the database.

- The client machine must be able to connect to WarehousePG coordinator host.

  If necessary, add the WarehousePG coordinator host name and IP address to the system `hosts` file. On Linux systems, the `hosts` file is in `/etc`.

Required Software on the Client Machine

- The Kerberos `kinit` utility is required on the client machine. The `kinit` utility is available when you install the Kerberos packages:

  - krb5-libs
  - krb5-workstation

  > **Note** When you install the Kerberos packages, you can use other Kerberos utilities such as `klist` to display Kerberos ticket information.

Java applications require this additional software:

- Java JDK

  Java JDK 1.7.0_17 is supported on Red Hat Enterprise Linux 6.x.

- Ensure that JAVA_HOME is set to the installation directory of the supported Java JDK.

Setting Up Client System with Kerberos Authentication

To connect to WarehousePG with Kerberos authentication requires a Kerberos ticket. On client systems, tickets are generated from Kerberos keytab files with the `kinit` utility and are stored in a cache file.

1. Install a copy of the Kerberos configuration file `krb5.conf` from the WarehousePG coordinator. The file is used by the WarehousePG client software and the Kerberos utilities.

   Install `krb5.conf` in the directory `/etc`.

   If needed, add the parameter `default_ccache_name` to the `[libdefaults]` section of the `krb5.ini` file and specify location of the Kerberos ticket cache file on the client system.

2. Obtain a Kerberos keytab file that contains the authentication credentials for the WarehousePG user.

3. Run `kinit` specifying the keytab file to create a ticket on the client machine. For this example, the keytab file `gpdb-kerberos.keytab` is in the current directory. The ticket cache file is in the `gpadmin` user home directory.

   ```
   > kinit -k -t gpdb-kerberos.keytab -c /home/gpadmin/cache.txt
     gpadmin/kerberos-gpdb@KRB.EXAMPLE.COM
   ```

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Running psql

From a remote system, you can access a WarehousePG that has Kerberos authentication enabled.

To connect to WarehousePG with psql

1. As the gpadmin user, open a command window.
2. Start `psql` from the command window and specify a connection to the WarehousePG specifying the user that is configured with Kerberos authentication.

   The following example logs into the WarehousePG on the machine `kerberos-gpdb` as the `gpadmin` user with the Kerberos credentials `gpadmin/kerberos-gpdb`:

   ```
   $ psql -U "gpadmin/kerberos-gpdb" -h kerberos-gpdb postgres
   ```

Running a Java Application

Accessing WarehousePG from a Java application with Kerberos authentication uses the Java Authentication and Authorization Service (JAAS)

1. Create the file `.java.login.config` in the user home folder.

   For example, on a Linux system, the home folder is similar to `/home/gpadmin`.

   Add the following text to the file:

   ```
   pgjdbc {
     com.sun.security.auth.module.Krb5LoginModule required
     doNotPrompt=true
     useTicketCache=true
     ticketCache = "/home/gpadmin/cache.txt"
     debug=true
     client=true;
   };
   ```

2. Create a Java application that connects to WarehousePG using Kerberos authentication and run the application as the user.

This example database connection URL uses a PostgreSQL JDBC driver and specifies parameters for Kerberos authentication.

```
jdbc:postgresql://kerberos-gpdb:5432/mytest?
  kerberosServerName=postgres&jaasApplicationName=pgjdbc&
  user=gpadmin/kerberos-gpdb
```

The parameter names and values specified depend on how the Java application performs Kerberos authentication.

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4.3.1.4 Configuring Kerberos For Windows Clients

You can configure Microsoft Windows client applications to connect to a WarehousePG cluster that is configured to authenticate with Kerberos.

When a WarehousePG cluster is configured to authenticate with Kerberos, you can configure Kerberos authentication for the WarehousePG client utilities `gpload` and `psql` on a Microsoft Windows system. The WarehousePG clients authenticate with Kerberos directly.

This section contains the following information.

- Installing and Configuring Kerberos on a Windows System
- Running the psql Utility
- Example gpload YAML File
- Creating a Kerberos Keytab File
- Issues and Possible Solutions

These topics assume that the WarehousePG cluster is configured to authenticate with Kerberos. For information about configuring WarehousePG with Kerberos authentication, refer to Using Kerberos Authentication.

Parent topic: Configuring Client Authentication

Installing and Configuring Kerberos on a Windows System

The `kinit`, `kdestroy`, and `klist` MIT Kerberos Windows client programs and supporting libraries are installed on your system when you install the WarehousePG Client and Load Tools package:

- `kinit` - generate a Kerberos ticket
- `kdestroy` - destroy active Kerberos tickets
- `klist` - list Kerberos tickets

You must configure Kerberos on the Windows client to authenticate with WarehousePG:

1. Copy the Kerberos configuration file `/etc/krb5.conf` from the WarehousePG coordinator to the Windows system, rename it to `krb5.ini`, and place it in the default Kerberos location on the Windows system, `C:\ProgramData\MIT\Kerberos5\krb5.ini`. This directory may be hidden. This step requires administrative privileges on the Windows client system. You may also choose to place the `/etc/krb5.ini` file in a custom location. If you choose to do this, you must configure and set a system environment variable named `KRB5_CONFIG` to the custom location.

2. Locate the `[libdefaults]` section of the `krb5.ini` file, and remove the entry identifying the location of the Kerberos credentials cache file, `default_ccache_name`. This step requires administrative privileges on the Windows client system.

   This is an example configuration file with `default_ccache_name` removed. The `[logging]` section is also removed.

   ```
   [libdefaults]
    debug = true
    default_etypes = aes256-cts-hmac-sha1-96
    default_realm = EXAMPLE.LOCAL
    dns_lookup_realm = false
    dns_lookup_kdc = false
    ticket_lifetime = 24h
    renew_lifetime = 7d
    forwardable = true

   [realms]
    EXAMPLE.LOCAL = {
     kdc =bocdc.example.local
     admin_server = bocdc.example.local
    }

   [domain_realm]
    .example.local = EXAMPLE.LOCAL
    example.local = EXAMPLE.LOCAL
   ```

3. Set up the Kerberos credential cache file. On the Windows system, set the environment variable `KRB5CCNAME` to specify the file system location of the cache file. The file must be named `krb5cache`. This location identifies a file, not a directory, and should be unique to each login on the server. When you set `KRB5CCNAME`, you can specify the value in either a local user environment or within a session. For example, the following command sets `KRB5CCNAME` in the session:

   ```
   set KRB5CCNAME=%USERPROFILE%\krb5cache
   ```

4. Obtain your Kerberos principal and password or keytab file from your system administrator.

5. Generate a Kerberos ticket using a password or a keytab. For example, to generate a ticket using a password:

   ```
   kinit [<principal>]
   ```

   To generate a ticket using a keytab (as described in Creating a Kerberos Keytab File):

   ```
   kinit -k -t <keytab_filepath> [<principal>]
   ```

6. Set up the WarehousePG clients environment:

   ```
   set PGGSSLIB=gssapi
   "c:\Program Files\WarehousePG\greenplum-clients\greenplum_clients_path.bat"
   ```

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Running the psql Utility

After you configure Kerberos and generate the Kerberos ticket on a Windows system, you can run the WarehousePG command line client `psql`.

If you get warnings indicating that the Console code page differs from Windows code page, you can run the Windows utility `chcp` to change the code page. This is an example of the warning and fix:

```
psql -h prod1.example.local warehouse
psql (9.4.20)
WARNING: Console code page (850) differs from Windows code page (1252)
 8-bit characters might not work correctly. See psql reference
 page "Notes for Windows users" for details.
Type "help" for help.

warehouse=# \q

chcp 1252
Active code page: 1252

psql -h prod1.example.local warehouse
psql (9.4.20)
Type "help" for help.
```

Creating a Kerberos Keytab File

You can create and use a Kerberos `keytab` file to avoid entering a password at the command line or listing a password in a script file when you connect to a WarehousePG cluster, perhaps when automating a scheduled WarehousePG task such as `gpload`. You can create a keytab file with the Java JRE keytab utility `ktab`. If you use AES256-CTS-HMAC-SHA1-96 encryption, you need to download and install the Java extension *Java Cryptography Extension (JCE) Unlimited Strength Jurisdiction Policy Files for JDK/JRE* from Oracle.

> **Note** You must enter the password to create a keytab file. The password is visible onscreen as you enter it.

This example runs the Java `ktab.exe` program to create a keytab file (`-a` option) and list the keytab name and entries (`-l` `-e` `-t` options).

```
C:\Users\dev1>"\Program Files\Java\jre1.8.0_77\bin"\ktab -a dev1
Password for dev1@EXAMPLE.LOCAL:<your_password>
Done!
Service key for dev1 is saved in C:\Users\dev1\krb5.keytab

C:\Users\dev1>"\Program Files\Java\jre1.8.0_77\bin"\ktab -l -e -t
Keytab name: C:\Users\dev1\krb5.keytab
KVNO Timestamp Principal
---- -------------- ------------------------------------------------------
 4 13/04/16 19:14 dev1@EXAMPLE.LOCAL (18:AES256 CTS mode with HMAC SHA1-96)
 4 13/04/16 19:14 dev1@EXAMPLE.LOCAL (17:AES128 CTS mode with HMAC SHA1-96)
 4 13/04/16 19:14 dev1@EXAMPLE.LOCAL (16:DES3 CBC mode with SHA1-KD)
 4 13/04/16 19:14 dev1@EXAMPLE.LOCAL (23:RC4 with HMAC)
```

You can then generate a Kerberos ticket using a keytab with the following command:

```
kinit -kt dev1.keytab dev1
```

or

```
kinit -kt %USERPROFILE%\krb5.keytab dev1
```

Example gpload YAML File

When you initiate a `gpload` job to a WarehousePG cluster using Kerberos authentication, you omit the `USER:` property and value from the YAML control file.

This example `gpload` YAML control file named `test.yaml` does not include a `USER:` entry:

```
---
VERSION: 1.0.0.1
DATABASE: warehouse
HOST: prod1.example.local
PORT: 5432

GPLOAD:
   INPUT:
    - SOURCE:
         PORT_RANGE: [18080,18080]
         FILE:
           - /Users/dev1/Downloads/test.csv
    - FORMAT: text
    - DELIMITER: ','
    - QUOTE: '"'
    - ERROR_LIMIT: 25
    - LOG_ERRORS: true
   OUTPUT:
    - TABLE: public.test
    - MODE: INSERT
   PRELOAD:
    - REUSE_TABLES: true
```

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These commands run `kinit` using a keytab file, run `gpload.bat` with the `test.yaml` file, and then display successful `gpload` output.

```
kinit -kt %USERPROFILE%\krb5.keytab dev1

gpload.bat -f test.yaml
2016-04-10 16:54:12|INFO|gpload session started 2016-04-10 16:54:12
2016-04-10 16:54:12|INFO|started gpfdist -p 18080 -P 18080 -f "/Users/dev1/Downloads/test.csv" -t 30
2016-04-10 16:54:13|INFO|running time: 0.23 seconds
2016-04-10 16:54:13|INFO|rows Inserted = 3
2016-04-10 16:54:13|INFO|rows Updated = 0
2016-04-10 16:54:13|INFO|data formatting errors = 0
2016-04-10 16:54:13|INFO|gpload succeeded
```

Issues and Possible Solutions

- This message indicates that Kerberos cannot find your Kerberos credentials cache file:

  ```
  Credentials cache I/O operation failed XXX
  (Kerberos error 193)
  krb5_cc_default() failed
  ```

  To ensure that Kerberos can find the file, set the environment variable `KRB5CCNAME` and run `kinit`.

  ```
  set KRB5CCNAME=%USERPROFILE%\krb5cache
  kinit
  ```

- This `kinit` message indicates that the `kinit -k -t` command could not find the keytab.

  ```
  kinit: Generic preauthentication failure while getting initial credentials
  ```

  Confirm that the full path and filename for the Kerberos keytab file is correct.

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4.3.2 Managing Roles and Privileges

The WarehousePG authorization mechanism stores roles and permissions to access database objects in the database and is administered using SQL statements or command-line utilities.

WarehousePG manages database access permissions using *roles*. The concept of roles subsumes the concepts of *users* and *groups*. A role can be a database user, a group, or both. Roles can own database objects (for example, tables) and can assign privileges on those objects to other roles to control access to the objects. Roles can be members of other roles, thus a member role can inherit the object privileges of its parent role.

Every WarehousePG cluster contains a set of database roles (users and groups). Those roles are separate from the users and groups managed by the operating system on which the server runs. However, for convenience you may want to maintain a relationship between operating system user names and WarehousePG role names, since many of the client applications use the current operating system user name as the default.

In WarehousePG, users log in and connect through the coordinator instance, which then verifies their role and access privileges. The coordinator then issues commands to the segment instances behind the scenes as the currently logged in role.

Roles are defined at the system level, meaning they are valid for all databases in the system.

In order to bootstrap the WarehousePG cluster, a freshly initialized system always contains one predefined *superuser* role (also referred to as the system user). This role will have the same name as the operating system user that initialized the WarehousePG cluster. Customarily, this role is named `gpadmin`. In order to create more roles you first have to connect as this initial role.

Parent topic: Managing WarehousePG Access

Security Best Practices for Roles and Privileges

- **Secure the gpadmin system user.** WarehousePG requires a UNIX user id to install and initialize the WarehousePG cluster. This system user is referred to as `gpadmin` in the WarehousePG documentation. This `gpadmin` user is the default database superuser in WarehousePG, as well as the file system owner of the WarehousePG installation and its underlying data files. This default administrator account is fundamental to the design of WarehousePG. The system cannot run without it, and there is no way to limit the access of this gpadmin user id. Use roles to manage who has access to the database for specific purposes. You should only use the `gpadmin` account for system maintenance tasks such as expansion and upgrade. Anyone who logs on to a WarehousePG host as this user id can read, alter or delete any data; including system catalog data and database access rights. Therefore, it is very important to secure the gpadmin user id and only provide access to essential system administrators. Administrators should only log in to WarehousePG as `gpadmin` when performing certain system maintenance tasks (such as upgrade or expansion). Database users should never log on as `gpadmin`, and ETL or production workloads should never run as `gpadmin`.
- **Assign a distinct role to each user that logs in.** For logging and auditing purposes, each user that is allowed to log in to WarehousePG should be given their own database role. For applications or web services, consider creating a distinct role for each application or service. See Creating New Roles (Users).
- **Use groups to manage access privileges.** See Role Membership.
- **Limit users who have the SUPERUSER role attribute.** Roles that are superusers bypass all access privilege checks in WarehousePG, as well as resource queuing. Only system administrators should be given superuser rights. See Altering Role Attributes.

Creating New Roles (Users)

A user-level role is considered to be a database role that can log in to the database and initiate a database session. Therefore, when you create a new user-level role using the `CREATE ROLE` command, you must specify the `LOGIN` privilege. For example:

```
=# CREATE ROLE jsmith WITH LOGIN;
```

A database role may have a number of attributes that define what sort of tasks that role can perform in the database. You can set these attributes when you create the role, or later using the `ALTER ROLE` command.

Altering Role Attributes

A database role may have a number of attributes that define what sort of tasks that role can perform in the database.

Attributes	Description
`SUPERUSER` or `NOSUPERUSER`	Determines if the role is a superuser. You must yourself be a superuser to create a new superuser. `NOSUPERUSER` is the default.
`CREATEDB` or `NOCREATEDB`	Determines if the role is allowed to create databases. `NOCREATEDB` is the default.
`CREATEROLE` or `NOCREATEROLE`	Determines if the role is allowed to create and manage other roles. `NOCREATEROLE` is the default.
`INHERIT` or `NOINHERIT`	Determines whether a role inherits the privileges of roles it is a member of. A role with the `INHERIT` attribute can automatically use whatever database privileges have been granted to all roles it is directly or indirectly a member of. `INHERIT` is the default.
`LOGIN` or `NOLOGIN`	Determines whether a role is allowed to log in. A role having the `LOGIN` attribute can be thought of as a user. Roles without this attribute are useful for managing database privileges (groups). `NOLOGIN` is the default.
`CONNECTION LIMIT *connlimit*`	If role can log in, this specifies how many concurrent connections the role can make. -1 (the default) means no limit.
`CREATEEXTTABLE` or `NOCREATEEXTTABLE`	Determines whether a role is allowed to create external tables. `NOCREATEEXTTABLE` is the default. For a role with the `CREATEEXTTABLE` attribute, the default external table `type` is `readable` and the default `protocol` is `gpfdist`. Note that external tables that use the `file` or `execute` protocols can only be created by superusers.
`PASSWORD '*password*'`	Sets the role's password. If you do not plan to use password authentication you can omit this option. If no password is specified, the password will be set to null and password authentication will always fail for that user. A null password can optionally be written explicitly as `PASSWORD NULL`.
`ENCRYPTED`	The password is always stored encrypted in the system catalogs. The `ENCRYPTED` keyword has no effect, but is accepted for backwards compatibility. The method of encryption is determined by the configuration parameter `password_encryption`. If the presented password string is already in MD5-encrypted or SCRAM-encrypted format, then it is stored as-is regardless of `password_encryption`, since the system cannot decrypt the specified encrypted password string, to encrypt it in a different format). This allows reloading of encrypted passwords during dump/restore. See Protecting Passwords in WarehousePG for additional information about protecting login passwords.
`VALID UNTIL 'timestamp'`	Sets a date and time after which the role's password is no longer valid. If omitted the password will be valid for all time.

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Attributes	Description
`RESOURCE QUEUE queue_name`	Assigns the role to the named resource queue for workload management. Any statement that role issues is then subject to the resource queue's limits. Note that the `RESOURCE QUEUE` attribute is not inherited; it must be set on each user-level (`LOGIN`) role.
`DENY deny_interval` or `DENY deny_point`	Restricts access during an interval, specified by day or day and time. For more information see Time-based Authentication.

You can set these attributes when you create the role, or later using the `ALTER ROLE` command. For example:

```
=# ALTER ROLE jsmith WITH PASSWORD 'passwd123';
=# ALTER ROLE admin VALID UNTIL 'infinity';
=# ALTER ROLE jsmith LOGIN;
=# ALTER ROLE jsmith RESOURCE QUEUE adhoc;
=# ALTER ROLE jsmith DENY DAY 'Sunday';
```

A role can also have role-specific defaults for many of the server configuration settings. For example, to set the default schema search path for a role:

```
=# ALTER ROLE admin SET search_path TO myschema, public;
```

Role Membership

It is frequently convenient to group users together to ease management of object privileges: that way, privileges can be granted to, or revoked from, a group as a whole. In WarehousePG this is done by creating a role that represents the group, and then granting membership in the group role to individual user roles.

Use the `CREATE ROLE` SQL command to create a new group role. For example:

```
=# CREATE ROLE admin CREATEROLE CREATEDB;
```

Once the group role exists, you can add and remove members (user roles) using the `GRANT` and `REVOKE` commands. For example:

```
=# GRANT admin TO john, sally;
=# REVOKE admin FROM bob;
```

For managing object privileges, you would then grant the appropriate permissions to the group-level role only (see Managing Object Privileges). The member user roles then inherit the object privileges of the group role. For example:

```
=# GRANT ALL ON TABLE mytable TO admin;
=# GRANT ALL ON SCHEMA myschema TO admin;
=# GRANT ALL ON DATABASE mydb TO admin;
```

The role attributes `LOGIN` , `SUPERUSER` , `CREATEDB` , `CREATEROLE` , `CREATEEXTTABLE` , and `RESOURCE QUEUE` are never inherited as ordinary privileges on database objects are. User members must actually `SET ROLE` to a specific role having one of these attributes in order to make use of the attribute. In the above example, we gave `CREATEDB` and `CREATEROLE` to the `admin` role. If `sally` is a member of `admin` , then `sally` could issue the following command to assume the role attributes of the parent role:

```
=> SET ROLE admin;
```

Managing Object Privileges

When an object (table, view, sequence, database, function, language, schema, or tablespace) is created, it is assigned an owner. The owner is normally the role that ran the creation statement. For most kinds of objects, the initial state is that only the owner (or a superuser) can do anything with the object. To allow other roles to use it, privileges must be granted. WarehousePG supports the following privileges for each object type:

Table 2. Object Privileges

Object Type	Privileges

Tables, External Tables, Views	`SELECT`
	`INSERT`
	`UPDATE`
	`DELETE`
	`REFERENCES`
	`TRIGGER`
	`TRUNCATE`
	`ALL`

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Object Type	Privileges
Columns	`SELECT` `INSERT` `UPDATE` `REFERENCES` `ALL`
Sequences	`USAGE` `SELECT` `UPDATE` `ALL`
Databases	`CREATE` `CONNECT` `TEMPORARY` `TEMP` `ALL`
Domains	`USAGE` `ALL`
Foreign Data Wrappers	`USAGE` `ALL`
Foreign Servers	`USAGE` `ALL`
Functions	`EXECUTE` `ALL`
Procedural Languages	`USAGE` `ALL`
Schemas	`CREATE` `USAGE` `ALL`
Tablespaces	`CREATE` `ALL`
Types	`USAGE` `ALL`

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Object Type	Privileges

Protocols	`SELECT`
	`INSERT`
	`ALL`

> **Note** You must grant privileges for each object individually. For example, granting `ALL` on a database does not grant full access to the objects within that database. It only grants all of the database-level privileges (`CONNECT` , `CREATE` , `TEMPORARY`) to the database itself.

Use the `GRANT` SQL command to give a specified role privileges on an object. For example, to grant the role named `jsmith` insert privileges on the table named `mytable` :

```
=# GRANT INSERT ON mytable TO jsmith;
```

Similarly, to grant `jsmith` select privileges only to the column named `col1` in the table named `table2` :

```
=# GRANT SELECT (col1) on TABLE table2 TO jsmith;
```

To revoke privileges, use the `REVOKE` command. For example:

```
=# REVOKE ALL PRIVILEGES ON mytable FROM jsmith;
```

You can also use the `DROP OWNED` and `REASSIGN OWNED` commands for managing objects owned by deprecated roles (Note: only an object's owner or a superuser can drop an object or reassign ownership). For example:

```
=# REASSIGN OWNED BY sally TO bob;
=# DROP OWNED BY visitor;
```

Encrypting Data

WarehousePG is installed with an optional module of encryption/decryption functions called `pgcrypto` . The `pgcrypto` functions allow database administrators to store certain columns of data in encrypted form. This adds an extra layer of protection for sensitive data, as data stored in WarehousePG in encrypted form cannot be read by anyone who does not have the encryption key, nor can it be read directly from the disks.

> **Note** The `pgcrypto` functions run inside the database server, which means that all the data and passwords move between `pgcrypto` and the client application in clear-text. For optimal security, consider also using SSL connections between the client and the WarehousePG coordinator server.

To use `pgcrypto` functions, register the `pgcrypto` extension in each database in which you want to use the functions. For example:

```
psql -d testdb -c "CREATE EXTENSION pgcrypto"
```

See pgcrypto in the PostgreSQL documentation for more information about individual functions.

Protecting Passwords in WarehousePG

In its default configuration, WarehousePG saves MD5 or SCRAM-SHA-256 hashes of login users' passwords in the `pg_authid` system catalog rather than saving clear text passwords. Anyone who is able to view the `pg_authid` table can see hash strings, but no passwords. This also ensures that passwords are obscured when the database is dumped to backup files.

The hash function runs when the password is set by using any of the following commands:

- `CREATE USER name WITH PASSWORD 'password'`
- `CREATE ROLE name WITH LOGIN PASSWORD 'password'`
- `ALTER USER name WITH PASSWORD 'password'`
- `ALTER ROLE name WITH PASSWORD 'password'`

> **Note** The SQL command syntax and `password_encryption` configuration variable include the term *encrypt*, but the passwords are not technically encrypted. They are *hashed* and therefore cannot be decrypted.

The hash is calculated on the concatenated clear text password and role name. The MD5 hash produces a 32-byte hexadecimal string prefixed with the characters `md5` while the SCRAM-SHA-256 hash produces a 64-byte hexadecimal string prefixed with the characters `SCRAM-SHA-256` . The hashed password is saved in the `rolpassword` column of the `pg_authid` system table.

To set `password_encryption` globally, run these commands in a shell as the `gpadmin` user:

```
$ gpconfig -c password_encryption -v 'scram-sha-256'
$ gpstop -u
```

To set `password_encryption` in a session, use the SQL `SET` command:

```
SET password_encryption = 'md5';
```

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Time-based Authentication

WarehousePG enables the administrator to restrict access to certain times by role. Use the `CREATE ROLE` or `ALTER ROLE` commands to specify time-based constraints.

For details, refer to the *WarehousePG Security Configuration Guide*.

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4.3.3 About Configuring Row-Level Security Policies

In addition to the SQL-standard privilege system available through GRANT, tables can have row security policies that restrict, on a per-user basis, which rows can be returned by normal queries or inserted, updated, or deleted by data modification commands. This feature is also known as *Row-Level Security*. By default, tables do not have any policies, so that if a user has access privileges to a table according to the SQL privilege system, all rows within it are equally available for querying or updating.

When row security is enabled on a table (with `ALTER TABLE ... ENABLE ROW LEVEL SECURITY`), all normal access to the table for selecting rows or modifying rows must be allowed by a row security policy. (However, the table's owner is typically not subject to row security policies.) If no policy exists for the table, a default-deny policy is used, meaning that no rows are visible or can be modified. Operations that apply to the whole table, such as `TRUNCATE` and `REFERENCES`, are not subject to row security.

Row security policies can be specific to commands, or to roles, or to both. A policy can be specified to apply to `ALL` commands, or to `SELECT`, `INSERT`, `UPDATE`, or `DELETE`. Multiple roles can be assigned to a given policy, and normal role membership and inheritance rules apply.

To specify which rows are visible or modifiable according to a policy, an expression is required that returns a Boolean result. This expression will be evaluated for each row prior to any conditions or functions coming from the user's query. (The only exceptions to this rule are leakproof functions, which are guaranteed to not leak information; the optimizer may choose to apply such functions ahead of the row-security check.) Rows for which the expression does not return true will not be processed. Separate expressions may be specified to provide independent control over the rows which are visible and the rows which are allowed to be modified. Policy expressions are run as part of the query and with the privileges of the user running the query, although security-definer functions can be used to access data not available to the calling user.

Superusers and roles with the `BYPASSRLS` attribute always bypass the row security system when accessing a table. Table owners normally bypass row security as well, though a table owner can choose to be subject to row security with `ALTER TABLE ... FORCE ROW LEVEL SECURITY`.

Enabling and disabling row security, as well as adding policies to a table, is always the privilege of the table owner only.

You create policies using the CREATE POLICY command, alter policies using the ALTER POLICY command, and drop policies using the DROP POLICY command. To enable and disable row security for a given table, use the ALTER TABLE command.

Each policy has a name, and you can define multiple policies for a table. As policies are table-specific, each policy for a table must have a unique name. Different tables may have policies with the same name.

When multiple policies apply to a given query, they are combined using either `OR` (for permissive policies, which are the default) or using `AND` (for restrictive policies). This is similar to the rule that a given role has the privileges of all roles of which they are a member. Permissive vs. restrictive policies are discussed further below.

Here is a simple example that creates a policy on the `account` relation to allow only members of the `managers` role to access rows, and only rows of their accounts:

```
CREATE TABLE accounts (manager text, company text, contact_email text);

ALTER TABLE accounts ENABLE ROW LEVEL SECURITY;

CREATE POLICY account_managers ON accounts TO managers
    USING (manager = current_user);
```

The policy above implicitly provides a `WITH CHECK` clause identical to its `USING` clause, so that the constraint applies both to rows selected by a command (so a manager cannot `SELECT`, `UPDATE`, or `DELETE` existing rows belonging to a different manager) and to rows modified by a command (so rows belonging to a different manager cannot be created via `INSERT` or `UPDATE`).

If no role is specified, or the special user name `PUBLIC` is used, then the policy applies to all users on the system. To allow all users to access only their own row in a `users` table, you can create a simple policy as follows:

```
CREATE POLICY user_policy ON users
    USING (user_name = current_user);
```

This works similarly to the previous example.

To use a different policy for rows that are being added to the table compared to those rows that are visible, you can combine multiple policies. This pair of policies would allow all users to view all rows in the `users` table, but modify only their own:

```
CREATE POLICY user_sel_policy ON users
    FOR SELECT
    USING (true);
CREATE POLICY user_mod_policy ON users
    USING (user_name = current_user);
```

In a `SELECT` command, these two policies are combined using `OR`, with the net effect being that all rows can be selected. In other command types, only the second policy applies, so that the effects are the same as before.

Row security can also be disabled with the `ALTER TABLE` command. Disabling row security does not remove any policies that are defined on the table; they are simply ignored. Then all rows in the table are visible and modifiable, subject to the standard SQL privileges system.

The example below is more comprehensive. The table `passwd` emulates a Unix password file:

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```
-- Simple passwd-file based example
CREATE TABLE passwd (
  user_name             text UNIQUE NOT NULL,
  pwhash                text,
  uid                   int  PRIMARY KEY,
  gid                   int  NOT NULL,
  real_name             text NOT NULL,
  home_phone            text,
  extra_info            text,
  home_dir              text NOT NULL,
  shell                 text NOT NULL
);

CREATE ROLE admin;  -- Administrator
CREATE ROLE bob;    -- Normal user
CREATE ROLE alice;  -- Normal user

-- Populate the table
INSERT INTO passwd VALUES
  ('admin','xxx',0,0,'Admin','111-222-3333',null,'/root','/bin/dash');
INSERT INTO passwd VALUES
  ('bob','xxx',1,1,'Bob','123-456-7890',null,'/home/bob','/bin/zsh');
INSERT INTO passwd VALUES
  ('alice','xxx',2,1,'Alice','098-765-4321',null,'/home/alice','/bin/zsh');

-- Be sure to enable row level security on the table
ALTER TABLE passwd ENABLE ROW LEVEL SECURITY;

-- Create policies
-- Administrator can see all rows and add any rows
CREATE POLICY admin_all ON passwd TO admin USING (true) WITH CHECK (true);
-- Normal users can view all rows
CREATE POLICY all_view ON passwd FOR SELECT USING (true);
-- Normal users can update their own records, but
-- limit which shells a normal user is allowed to set
CREATE POLICY user_mod ON passwd FOR UPDATE
  USING (current_user = user_name)
  WITH CHECK (
    current_user = user_name AND
    shell IN ('/bin/bash','/bin/sh','/bin/dash','/bin/zsh','/bin/tcsh')
  );

-- Allow admin all normal rights
GRANT SELECT, INSERT, UPDATE, DELETE ON passwd TO admin;
-- Users only get select access on public columns
GRANT SELECT
  (user_name, uid, gid, real_name, home_phone, extra_info, home_dir, shell)
  ON passwd TO public;
-- Allow users to update certain columns
GRANT UPDATE
  (pwhash, real_name, home_phone, extra_info, shell)
  ON passwd TO public;
```

As with any security settings, it's important to test and ensure that the system is behaving as expected. Using the example above, this demonstrates that the permission system is working properly.

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```
-- admin can view all rows and fields
postgres=> set role admin;
SET
postgres=> table passwd;
 user_name | pwhash | uid | gid | real_name |  home_phone  | extra_info | home_dir    |   shell
-----------+--------+-----+-----+-----------+--------------+------------+-------------+-----------
 admin     | xxx    |   0 |   0 | Admin     | 111-222-3333 |            | /root       | /bin/dash
 bob       | xxx    |   1 |   1 | Bob       | 123-456-7890 |            | /home/bob   | /bin/zsh
 alice     | xxx    |   2 |   1 | Alice     | 098-765-4321 |            | /home/alice | /bin/zsh
(3 rows)

-- Test what Alice is able to do
postgres=> set role alice;
SET
postgres=> table passwd;
ERROR:  permission denied for relation passwd
postgres=> select user_name,real_name,home_phone,extra_info,home_dir,shell from passwd;
 user_name | real_name |  home_phone  | extra_info | home_dir    |   shell
-----------+-----------+--------------+------------+-------------+-----------
 admin     | Admin     | 111-222-3333 |            | /root       | /bin/dash
 bob       | Bob       | 123-456-7890 |            | /home/bob   | /bin/zsh
 alice     | Alice     | 098-765-4321 |            | /home/alice | /bin/zsh
(3 rows)

postgres=> update passwd set user_name = 'joe';
ERROR:  permission denied for relation passwd
-- Alice is allowed to change her own real_name, but no others
postgres=> update passwd set real_name = 'Alice Doe';
UPDATE 1
postgres=> update passwd set real_name = 'John Doe' where user_name = 'admin';
UPDATE 0
postgres=> update passwd set shell = '/bin/xx';
ERROR:  new row violates WITH CHECK OPTION for "passwd"
postgres=> delete from passwd;
ERROR:  permission denied for relation passwd
postgres=> insert into passwd (user_name) values ('xxx');
ERROR:  permission denied for relation passwd
-- Alice can change her own password; RLS silently prevents updating other rows
postgres=> update passwd set pwhash = 'abc';
UPDATE 1
```

All of the policies constructed thus far have been permissive policies; this means that when multiple policies are applied they are combined using the `OR` Boolean operator. While permissive policies can be constructed to only allow access to rows in the intended cases, it can be simpler to combine permissive policies with restrictive policies (which the records must pass and which are combined using the `AND` Boolean operator). Building on the example above, we add a restrictive policy to require the administrator to be connected over a local Unix socket to access the records of the `passwd` table:

```
CREATE POLICY admin_local_only ON passwd AS RESTRICTIVE TO admin
    USING (pg_catalog.inet_client_addr() IS NULL);
```

We can then see that an administrator connecting over a network will not see any records, due to the restrictive policy:

```
=> SELECT current_user;
 current_user
--------------
 admin
(1 row)

=> select inet_client_addr();
 inet_client_addr
------------------
 127.0.0.1
(1 row)

=> SELECT current_user;
 current_user
--------------
 admin
(1 row)

=> TABLE passwd;
 user_name | pwhash | uid | gid | real_name | home_phone | extra_info | home_dir | shell
-----------+--------+-----+-----+-----------+------------+------------+----------+-------
(0 rows)

=> UPDATE passwd set pwhash = NULL;
UPDATE 0
```

Referential integrity checks, such as unique or primary key constraints and foreign key references, always bypass row security to ensure that data integrity is maintained. Take care when developing schemas and row-level policies to avoid "covert channel" leaks of information through such referential integrity checks.

In some contexts, it is important to be sure that row security is not being applied. For example, when taking a backup, it could be disastrous if row security silently caused some rows to be omitted from the backup. In such a situation, you can set the row_security configuration parameter to `off`. This does not in itself bypass row security; what it does is throw an error if any query's results would get filtered by a policy. You can then investigate the reason for the error and fix it.

In the examples above, the policy expressions consider only the current values in the row to be accessed or updated. This is the simplest and best-performing case; when possible, it is best to design row security applications to work this way. If it is necessary to consult other rows or other tables to make a policy decision, that can be accomplished using sub-`SELECT`s, or functions that contain `SELECT`s, in the policy expressions. Be aware, however, that such accesses can create race conditions that could allow information leakage if care is not taken. As an example, consider the following table design:

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```
-- definition of privilege groups
CREATE TABLE groups (group_id int PRIMARY KEY,
                     group_name text NOT NULL);

INSERT INTO groups VALUES
  (1, 'low'),
  (2, 'medium'),
  (5, 'high');

GRANT ALL ON groups TO alice;  -- alice is the administrator
GRANT SELECT ON groups TO public;

-- definition of users' privilege levels
CREATE TABLE users (user_name text PRIMARY KEY,
                    group_id int NOT NULL REFERENCES groups);

INSERT INTO users VALUES
  ('alice', 5),
  ('bob', 2),
  ('mallory', 2);

GRANT ALL ON users TO alice;
GRANT SELECT ON users TO public;

-- table holding the information to be protected
CREATE TABLE information (info text,
                          group_id int NOT NULL REFERENCES groups);

INSERT INTO information VALUES
  ('barely secret', 1),
  ('slightly secret', 2),
  ('very secret', 5);

ALTER TABLE information ENABLE ROW LEVEL SECURITY;

-- a row should be visible to/updatable by users whose security group_id is
-- greater than or equal to the row's group_id
CREATE POLICY fp_s ON information FOR SELECT
  USING (group_id <= (SELECT group_id FROM users WHERE user_name = current_user));
CREATE POLICY fp_u ON information FOR UPDATE
  USING (group_id <= (SELECT group_id FROM users WHERE user_name = current_user));

-- we rely only on RLS to protect the information table
GRANT ALL ON information TO public;
```

Now suppose that `alice` wishes to change the "slightly secret" information, but decides that `mallory` should not be trusted with the new content of that row, so she runs the following commands:

```
BEGIN;
UPDATE users SET group_id = 1 WHERE user_name = 'mallory';
UPDATE information SET info = 'secret from mallory' WHERE group_id = 2;
COMMIT;
```

That looks safe; there is no window wherein `mallory` should be able to see the `"secret from mallory"` string. However, there is a race condition here. If `mallory` is concurrently doing, say,

```
SELECT * FROM information WHERE group_id = 2 FOR UPDATE;
```

and her transaction is in `READ COMMITTED` mode, it is possible for her to see `"secret from mallory"`. That happens if her transaction reaches the information row just after `alice`'s does. It blocks waiting for `alice`'s transaction to commit, then fetches the updated row contents thanks to the `FOR UPDATE` clause. However, it does not fetch an updated row for the implicit `SELECT` from `users`, because that sub- `SELECT` did not have `FOR UPDATE`; instead the `users` row is read with the snapshot taken at the start of the query. Therefore, the policy expression tests the old value of `mallory`'s privilege level and allows her to see the updated row.

There are several ways around this problem. One simple answer is to use `SELECT ... FOR SHARE` in sub- `SELECT`s in row security policies. However, that requires granting `UPDATE` privilege on the referenced table (here `users`) to the affected users, which might be undesirable. (But another row security policy could be applied to prevent them from actually exercising that privilege; or the sub `SELECT` could be embedded into a security definer function.) Also, heavy concurrent use of row share locks on the referenced table could pose a performance problem, especially if updates of it are frequent. Another solution, practical if updates of the referenced table are infrequent, is to take an `ACCESS EXCLUSIVE` lock on the referenced table when updating it, so that no concurrent transactions could be examining old row values. Or one could just wait for all concurrent transactions to end after committing an update of the referenced table and before making changes that rely on the new security situation.

For additional details see CREATE POLICY and ALTER TABLE.

About Row-Level Security for Views

You can simulate row-level access by using views to restrict the rows that are selected. You can simulate row-level labels by adding an extra column to the table to store sensitivity information, and then using views to control row-level access based on this column. You can then grant roles access to the views rather than to the base table.

While views can hide the contents of certain columns, they cannot be used to reliably conceal the data in unseen rows. When it is necessary for a view to provide row-level security, you must apply the `security_barrier` attribute to the view. This prevents maliciously-chosen functions and operators from being passed values from rows until after the view has done its work. For example, this view is secure:

```
CREATE VIEW phone_number WITH (security_barrier) AS
    SELECT person, phone FROM phone_data WHERE phone NOT LIKE '412%';
```

Views created with the `security_barrier` attribute may perform far worse than views created without this option. In general, there is no way to avoid this: the fastest possible plan must be rejected if it may compromise security. For this reason, the `security_barrier` option is not enabled by default.

Be sure to review Rules and Privileges in the PostgreSQL documentation for detailed information about securing views.

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4.4 DDL: Defining Database Objects

This section covers data definition language (DDL) in WarehousePG and how to create and manage database objects.

Creating objects in a WarehousePG includes making up-front choices about data distribution, storage options, data loading, and other WarehousePG features that will affect the ongoing performance of your database system. Understanding the options that are available and how the database will be used will help you make the right decisions.

Most of the advanced WarehousePG features are enabled with extensions to the SQL `CREATE` DDL statements.

- Creating and Managing Databases
- Creating and Managing Tablespaces
- Creating and Managing Schemas
- About Table Definition Basics
- Creating and Managing Tables
- Choosing the Table Storage Model
- Partitioning Large Tables
- Creating and Using Sequences
- Using Indexes in WarehousePG
- Creating and Managing Views
- Creating and Managing Materialized Views

Parent topic: WarehousePG Administrator Guide

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4.4.1 Creating and Managing Databases

A WarehousePG cluster is a single instance of WarehousePG. There can be several separate WarehousePG clusters installed, but usually just one is selected by environment variable settings. See your WarehousePG administrator for details.

There can be multiple databases in a WarehousePG cluster. This is different from some database management systems (such as Oracle) where the database instance *is* the database. Although you can create many databases in a WarehousePG cluster, client programs can connect to and access only one database at a time — you cannot cross-query between databases.

Parent topic: DDL: Defining Database Objects

About Template and Default Databases

WarehousePG provides some template databases and a default database, *template1*, *template0*, and *postgres*.

By default, each new database you create is based on a *template* database. WarehousePG uses *template1* to create databases unless you specify another template. Creating objects in *template1* is not recommended. The objects will be in every database you create using the default template database.

WarehousePG uses another database template, *template0*, internally. Do not drop or modify *template0*. You can use *template0* to create a completely clean database containing only the standard objects predefined by WarehousePG at initialization.

You can use the *postgres* database to connect to WarehousePG for the first time. WarehousePG uses *postgres* as the default database for administrative connections. For example, *postgres* is used by startup processes, the Global Deadlock Detector process, and the FTS (Fault Tolerance Server) process for catalog access.

Creating a Database

The `CREATE DATABASE` command creates a new database. For example:

```
=> CREATE DATABASE <new_dbname>;
```

To create a database, you must have privileges to create a database or be a WarehousePG superuser. If you do not have the correct privileges, you cannot create a database. Contact your WarehousePG administrator to either give you the necessary privilege or to create a database for you.

You can also use the client program `createdb` to create a database. For example, running the following command in a command line terminal connects to WarehousePG using the provided host name and port and creates a database named *mydatabase*:

```
$ createdb -h coordinator_host -p 5432 mydatabase
```

The host name and port must match the host name and port of the installed WarehousePG cluster.

Some objects, such as roles, are shared by all the databases in a WarehousePG cluster. Other objects, such as tables that you create, are known only in the database in which you create them.

> **Caution** The `CREATE DATABASE` command is not transactional.

Cloning a Database

By default, a new database is created by cloning the standard system database template, *template1*. Any database can be used as a template when creating a new database, thereby providing the capability to 'clone' or copy an existing database and all objects and data within that database. For example:

```
=> CREATE DATABASE <new_dbname> TEMPLATE <old_dbname>;
```

Creating a Database with a Different Owner

Another database owner can be assigned when a database is created:

```
=> CREATE DATABASE <new_dbname> WITH <owner=new_user>;
```

Viewing the List of Databases

If you are working in the `psql` client program, you can use the `\l` meta-command to show the list of databases and templates in your WarehousePG cluster. If using another client program and you are a superuser, you can query the list of databases from the `pg_database` system catalog table. For example:

```
=> SELECT datname from pg_database;
```

Altering a Database

The ALTER DATABASE command changes database attributes such as owner, name, or default configuration attributes. For example, the following command alters a database by setting its default schema search path (the `search_path` configuration parameter):

```
=> ALTER DATABASE mydatabase SET search_path TO myschema, public, pg_catalog;
```

To alter a database, you must be the owner of the database or a superuser.

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Dropping a Database

The `DROP DATABASE` command drops (or deletes) a database. It removes the system catalog entries for the database and deletes the database directory on disk that contains the data. You must be the database owner or a superuser to drop a database, and you cannot drop a database while you or anyone else is connected to it. Connect to `postgres` (or another database) before dropping a database. For example:

```
=> \c postgres
=> DROP DATABASE mydatabase;
```

You can also use the client program `dropdb` to drop a database. For example, the following command connects to WarehousePG using the provided host name and port and drops the database *mydatabase*:

```
$ dropdb -h coordinator_host -p 5432 mydatabase
```

> **Caution** Dropping a database cannot be undone.

The `DROP DATABASE` command is not transactional.

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4.4.2 Creating and Managing Tablespaces

Tablespaces allow database administrators to have multiple file systems per machine and decide how to best use physical storage to store database objects. Tablespaces allow you to assign different storage for frequently and infrequently used database objects or to control the I/O performance on certain database objects. For example, place frequently-used tables on file systems that use high performance solid-state drives (SSD), and place other tables on standard hard drives.

A tablespace requires a host file system location to store its database files. In WarehousePG, the file system location must exist on all hosts including the hosts running the coordinator, standby coordinator, each primary segment, and each mirror segment.

A tablespace is WarehousePG cluster object (a global object), you can use a tablespace from any database if you have appropriate privileges.

> **Note** WarehousePG does not support different tablespace locations for a primary-mirror pair with the same content ID. It is only possible to configure different locations for different content IDs. Do not modify symbolic links under the `pg_tblspc` directory so that primary-mirror pairs point to different file locations; this will lead to erroneous behavior.

Parent topic: DDL: Defining Database Objects

Creating a Tablespace

The `CREATE TABLESPACE` command defines a tablespace. For example:

```
CREATE TABLESPACE fastspace LOCATION '/fastdisk/gpdb';
```

Database superusers define tablespaces and grant access to database users with the `GRANT``CREATE` command. For example:

```
GRANT CREATE ON TABLESPACE fastspace TO admin;
```

Using a Tablespace to Store Database Objects

Users with the `CREATE` privilege on a tablespace can create database objects in that tablespace, such as tables, indexes, and databases. The command is:

```
CREATE TABLE tablename(options) TABLESPACE spacename
```

For example, the following command creates a table in the tablespace*space1*:

```
CREATE TABLE foo(i int) TABLESPACE space1;
```

You can also use the `default_tablespace` parameter to specify the default tablespace for `CREATE TABLE` and `CREATE INDEX` commands that do not specify a tablespace:

```
SET default_tablespace = space1;
CREATE TABLE foo(i int);
```

There is also the `temp_tablespaces` configuration parameter, which determines the placement of temporary tables and indexes, as well as temporary files that are used for purposes such as sorting large data sets. This can be a comma-separate list of tablespace names, rather than only one, so that the load associated with temporary objects can be spread over multiple tablespaces. A random member of the list is picked each time a temporary object is to be created.

The tablespace associated with a database stores that database's system catalogs, temporary files created by server processes using that database, and is the default tablespace selected for tables and indexes created within the database, if no `TABLESPACE` is specified when the objects are created. If you do not specify a tablespace when you create a database, the database uses the same tablespace used by its template database.

You can use a tablespace from any database in the WarehousePG cluster if you have appropriate privileges.

Viewing Existing Tablespaces

Every WarehousePG cluster has the following default tablespaces.

- `pg_global` for shared system catalogs.
- `pg_default` , the default tablespace. Used by the *template1* and *template0* databases.

These tablespaces use the default system location, the data directory locations created at system initialization.

To see tablespace information, use the `pg_tablespace` catalog table to get the object ID (OID) of the tablespace and then use `gp_tablespace_location()` function to display the tablespace directories. This is an example that lists one user-defined tablespace, `myspace` :

```
SELECT oid, * FROM pg_tablespace ;

  oid  |  spcname   | spcowner | spcacl | spcoptions
-------+------------+----------+--------+------------
  1663 | pg_default |       10 |        |
  1664 | pg_global  |       10 |        |
 16391 | myspace    |       10 |        |
(3 rows)
```

The OID for the tablespace `myspace` is `16391` . Run `gp_tablespace_location()` to display the tablespace locations for a system that consists of two segment instances and the coordinator.

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```
# SELECT * FROM gp_tablespace_location(16391);
 gp_segment_id |    tblspc_loc
---------------+------------------
             0 | /data/mytblspace
             1 | /data/mytblspace
            -1 | /data/mytblspace
(3 rows)
```

This query uses `gp_tablespace_location()` the `gp_segment_configuration` catalog table to display segment instance information with the file system location for the `myspace` tablespace.

```
WITH spc AS (SELECT * FROM  gp_tablespace_location(16391))
  SELECT seg.role, spc.gp_segment_id as seg_id, seg.hostname, seg.datadir, tblspc_loc
    FROM spc, gp_segment_configuration AS seg
    WHERE spc.gp_segment_id = seg.content ORDER BY seg_id;
```

This is information for a test system that consists of two segment instances and the coordinator on a single host.

```
 role | seg_id | hostname |       datadir        |    tblspc_loc
------+--------+----------+----------------------+------------------
 p    |     -1 | testhost | /data/coordinator/gpseg-1 | /data/mytblspace
 p    |      0 | testhost | /data/data1/gpseg0   | /data/mytblspace
 p    |      1 | testhost | /data/data2/gpseg1   | /data/mytblspace
(3 rows)
```

Dropping Tablespaces

To drop a tablespace, you must be the tablespace owner or a superuser. You cannot drop a tablespace until all objects in all databases using the tablespace are removed.

The `DROP TABLESPACE` command removes an empty tablespace.

> **Note** You cannot drop a tablespace if it is not empty or if it stores temporary or transaction files.

Moving the Location of Temporary or Transaction Files

You can move temporary or transaction files to a specific tablespace to improve database performance when running queries, creating backups, and to store data more sequentially.

The WarehousePG server configuration parameter `temp_tablespaces` controls the location for both temporary tables and temporary spill files for hash aggregate and hash join queries. Temporary files for purposes such as sorting large data sets are also created in these tablespaces.

`temp_tablespaces` specifies tablespaces in which to create temporary objects (temp tables and indexes on temp tables) when a `CREATE` command does not explicitly specify a tablespace.

Also note the following information about temporary or transaction files:

- You can dedicate only one tablespace for temporary or transaction files, although you can use the same tablespace to store other types of files.
- You cannot drop a tablespace if it used by temporary files.

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4.4.3 Creating and Managing Schemas

Schemas logically organize objects and data in a database. Schemas allow you to have more than one object (such as tables) with the same name in the database without conflict if the objects are in different schemas.

Parent topic: DDL: Defining Database Objects

The Default "Public" Schema

Every database has a default schema named *public*. If you do not create any schemas, objects are created in the *public* schema. All database roles (users) have `CREATE` and `USAGE` privileges in the *public* schema. When you create a schema, you grant privileges to your users to allow access to the schema.

Creating a Schema

Use the `CREATE SCHEMA` command to create a new schema. For example:

```
=> CREATE SCHEMA myschema;
```

To create or access objects in a schema, write a qualified name consisting of the schema name and table name separated by a period. For example:

```
myschema.table
```

See Schema Search Paths for information about accessing a schema.

You can create a schema owned by someone else, for example, to restrict the activities of your users to well-defined namespaces. The syntax is:

```
=> CREATE SCHEMA `schemaname` AUTHORIZATION `username`;
```

Schema Search Paths

To specify an object's location in a database, use the schema-qualified name. For example:

```
=> SELECT * FROM myschema.mytable;
```

You can set the `search_path` configuration parameter to specify the order in which to search the available schemas for objects. The schema listed first in the search path becomes the *default* schema. If a schema is not specified, objects are created in the default schema.

Setting the Schema Search Path

The `search_path` configuration parameter sets the schema search order. The `ALTER DATABASE` command sets the search path. For example:

```
=> ALTER DATABASE mydatabase SET search_path TO myschema,
public, pg_catalog;
```

You can also set `search_path` for a particular role (user) using the `ALTER ROLE` command. For example:

```
=> ALTER ROLE sally SET search_path TO myschema, public,
pg_catalog;
```

Viewing the Current Schema

Use the `current_schema()` function to view the current schema. For example:

```
=> SELECT current_schema();
```

Use the `SHOW` command to view the current search path. For example:

```
=> SHOW search_path;
```

Dropping a Schema

Use the `DROP SCHEMA` command to drop (delete) a schema. For example:

```
=> DROP SCHEMA myschema;
```

By default, the schema must be empty before you can drop it. To drop a schema and all of its objects (tables, data, functions, and so on) use:

```
=> DROP SCHEMA myschema CASCADE;
```

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System Schemas

The following system-level schemas exist in every database:

- `pg_catalog` contains the system catalog tables, built-in data types, functions, and operators. It is always part of the schema search path, even if it is not explicitly named in the search path.
- `information_schema` consists of a standardized set of views that contain information about the objects in the database. These views get system information from the system catalog tables in a standardized way.
- `pg_toast` stores large objects such as records that exceed the page size. This schema is used internally by the WarehousePG cluster.
- `pg_bitmapindex` stores bitmap index objects such as lists of values. This schema is used internally by the WarehousePG cluster.
- `pg_aoseg` stores append-optimized table objects. This schema is used internally by the WarehousePG cluster.
- `gp_toolkit` is an administrative schema that contains external tables, views, and functions that you can access with SQL commands. All database users can access `gp_toolkit` to view and query the system log files and other system metrics.

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4.4.4 About Table Definition Basics

A table in a relational database is much like a table on paper: It consists of rows and columns. The number and order of the columns is fixed, and each column has a name. The number of rows is variable — it reflects how much data is stored at a given moment. SQL does not make any guarantees about the order of the rows in a table. When a table is read, the rows will appear in an unspecified order, unless sorting is explicitly requested. Furthermore, SQL does not assign unique identifiers to rows, so it is possible to have several completely identical rows in a table.

Each column has a data type. The data type constrains the set of possible values that can be assigned to a column and assigns semantics to the data stored in the column so that it can be used for computations. For instance, a column declared to be of a numerical type will not accept arbitrary text strings, and the data stored in such a column can be used for mathematical computations. By contrast, a column declared to be of a character string type will accept almost any kind of data but it does not lend itself to mathematical calculations, although other operations such as string concatenation are available.

WarehousePG includes a sizable set of built-in data types that fit many applications. Users can also define their own data types. Most built-in data types have obvious names and semantics. Some of the frequently used data types are `integer` for whole numbers, `numeric` for possibly fractional numbers, `text` for character strings, `date` for dates, `time` for time-of-day values, and `timestamp` for values containing both date and time.

To create a table, you use the aptly named CREATE TABLE command. In this command, you specify at least a name for the new table, the names of the columns and the data type of each column. For example:

```
CREATE TABLE my_first_table
(
    first_column text,
    second_column integer
);
```

This command creates a table named `my_first_table` with two columns. The first column is named `first_column` and has a data type of `text`; the second column has the name `second_column` and the type `integer`. The table and column names follow the identifier syntax explained in Identifiers and Key Words in the PostgreSQL documentation. The type names are usually also identifiers, but there are some exceptions. The column list is comma-separated and surrounded by parentheses.

Normally, you would specify names for your tables and columns that convey the kind of data that they store, for example:

```
CREATE TABLE products
(
    product_no integer,
    name text,
    price numeric
);
```

(The `numeric` type can store fractional components, as would be typical of monetary amounts.)

Tip: When you create many interrelated tables, it is wise to choose a consistent naming pattern for the tables and columns. For instance, you may choose using singular or plural nouns for table names.

WarehousePG limits the number of columns that a table can contain. Depending on the column types, the maximum is between 250 and 1600. Defining a table with anywhere near the maximum number of columns is highly unusual and often a questionable design.

If you no longer need a table, you can remove it using the DROP TABLE command. For example:

```
DROP TABLE my_first_table;
DROP TABLE products;
```

Attempting to drop a table that does not exist is an error. It is common in SQL script files to unconditionally try to drop each table before creating it, ignoring any error messages, so that the script works whether or not the table exists. You can use the `DROP TABLE IF EXISTS` variant to avoid the error messages, but this is not standard SQL.

Default Column Values

You can assign a column a default value. When a new row is created and no values are specified for some of the columns, WarehousePG assigns those columns their respective default values. A data manipulation command can also request explicitly that a column be set to its default value, without having to know what that value is.

If you do not explicitly declare a default for a column, the default value is the null value, which can be considered to represent unknown data.

In a table definition, specify the default value after the column data type. For example:

```
CREATE TABLE products
(
    product_no integer,
    name text,
    price numeric DEFAULT 9.99
);
```

The default value can be an expression, which WarehousePG evaluates whenever the default value is inserted (not when the table is created). A common example is for a timestamp column to have a default of `CURRENT_TIMESTAMP`, so that it gets set to the time of row insertion. Another common example is generating a "serial number" for each row. In WarehousePG, you can do this as follows:

```
CREATE TABLE products
(
    product_no integer DEFAULT
nextval('products_product_no_seq'),
    ...
);
```

where the `nextval()` function supplies successive values from a sequence object. This situation is sufficiently common that there's a special shorthand for it:

```
CREATE TABLE products (
    product_no SERIAL,
    ...
);
```

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Generated Columns

A generated column is a special column that is always computed from other columns; it is for columns what a view is for tables. There are two kinds of generated columns: stored and virtual. A stored generated column is computed when it is written (inserted or updated) and occupies storage as if it were a normal column. A virtual generated column occupies no storage and is computed when it is read.

A virtual generated column is similar to a view and a stored generated column is similar to a materialized view (except that it is always updated automatically). *WarehousePG currently implements only stored generated columns.*

To create a generated column, use the `GENERATED ALWAYS AS` clause in `CREATE TABLE`, for example:

```
CREATE TABLE people
(
    ...,
    height_cm numeric,
    height_in numeric GENERATED ALWAYS AS (height_cm / 2.54)
STORED
);
```

The keyword `STORED` must be specified to choose the stored kind of generated column. See CREATE TABLE for more details.

You cannot write directly to a generated column. While you may not specify a value for a generated column in an `INSERT` or `UPDATE` command, you can specify the keyword `DEFAULT`.

Note the following differences between a column with a default and a generated column:

- The column default is evaluated once when the row is first inserted if no other value was provided; a generated column is updated whenever the row changes and cannot be overridden.
- A column default may not refer to other columns of the table; a generation expression would normally do so.
- A column default can use volatile functions, for example `random()` or functions referring to the current time; WarehousePG does not permit this for generated columns.

Several restrictions apply to the definition of generated columns and tables involving generated columns:

- The generation expression can use only immutable functions and cannot use subqueries or reference anything other than the current row in any way.
- A generation expression cannot reference another generated column.
- A generation expression cannot reference a system column, except `tableoid`.
- A generated column cannot have a column default or an identity definition.
- A generated column cannot be used as a distribution key.
- A generated column cannot be part of a partition key.
- You may specify a generated column in a root partitioned table but not in a child table.
- For inheritance:
    - If a parent column is a generated column, a child column must also be a generated column using the same expression. Omit the `GENERATED` clause in the definition of the child column, it will be copied from the parent.
    - In the case of multiple inheritance, if one parent column is a generated column, then all parent columns must be generated columns and with the same expression.
    - If a parent column is not a generated column, a child column may be defined to be either a generated column or not.

Additional considerations apply to the use of generated columns:

- Foreign tables can have generated columns. See CREATE FOREIGN TABLE for details.
- Generated columns maintain access privileges separately from their underlying base columns. So, it is possible to grant privileges such that a particular role can read from a generated column but not from the underlying base columns.
- Generated columns are, conceptually, updated after `BEFORE` triggers have run. Changes made to base columns in a `BEFORE` trigger will be reflected in generated columns. But conversely, WarehousePG does not permit access to generated columns in `BEFORE` triggers.

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4.4.5 Creating and Managing Tables

WarehousePG tables are similar to tables in any relational database, except that table rows are distributed across the different segments in the system. When you create a table, you specify the table's distribution policy.

Creating a Table

The `CREATE TABLE` command creates a table and defines its structure. When you create a table, you define:

- The columns of the table and their associated data types. See Choosing Column Data Types.
- Any table or column constraints to limit the data that a column or table can contain. See Setting Table and Column Constraints.
- The distribution policy of the table, which determines how WarehousePG divides data across the segments. See Choosing the Table Distribution Policy.
- The way the table is stored on disk. See Choosing the Table Storage Model.
- The table partitioning strategy for large tables. See Creating and Managing Databases.

Choosing Column Data Types

The data type of a column determines the types of data values the column can contain. Choose the data type that uses the least possible space but can still accommodate your data and that best constrains the data. For example, use character data types for strings, date or timestamp data types for dates, and numeric data types for numbers.

For table columns that contain textual data, specify the data type `VARCHAR` or `TEXT` . Specifying the data type `CHAR` is not recommended. In WarehousePG, the data types `VARCHAR` or `TEXT` handle padding added to the data (space characters added after the last non-space character) as significant characters, the data type `CHAR` does not. For information on the character data types, see the `CREATE TABLE` command in the *WarehousePG Reference Guide*.

Use the smallest numeric data type that will accommodate your numeric data and allow for future expansion. For example, using `BIGINT` for data that fits in `INT` or `SMALLINT` wastes storage space. If you expect that your data values will expand over time, consider that changing from a smaller datatype to a larger datatype after loading large amounts of data is costly. For example, if your current data values fit in a `SMALLINT` but it is likely that the values will expand, `INT` is the better long-term choice.

Use the same data types for columns that you plan to use in cross-table joins. Cross-table joins usually use the primary key in one table and a foreign key in the other table. When the data types are different, the database must convert one of them so that the data values can be compared correctly, which adds unnecessary overhead.

WarehousePG has a rich set of native data types available to users. See the *WarehousePG Reference Guide* for information about the built-in data types.

Setting Table and Column Constraints

You can define constraints on columns and tables to restrict the data in your tables. WarehousePG support for constraints is the same as PostgreSQL with some limitations, including:

- `CHECK` constraints can refer only to the table on which they are defined.
- `UNIQUE` and `PRIMARY KEY` constraints must be compatible with their table's distribution key and partitioning key, if any.

  > **Note** `UNIQUE` and `PRIMARY KEY` constraints are not allowed on append-optimized tables because the `UNIQUE` indexes that are created by the constraints are not allowed on append-optimized tables.

- `FOREIGN KEY` constraints are allowed, but not enforced.
- Constraints that you define on partitioned tables apply to the partitioned table as a whole. You cannot define constraints on the individual parts of the table.

Check Constraints

Check constraints allow you to specify that the value in a certain column must satisfy a Boolean (truth-value) expression. For example, to require positive product prices:

```
=> CREATE TABLE products
            ( product_no integer,
              name text,
              price numeric CHECK (price > 0) );
```

Not-Null Constraints

Not-null constraints specify that a column must not assume the null value. A not-null constraint is always written as a column constraint. For example:

```
=> CREATE TABLE products
       ( product_no integer NOT NULL,
         name text NOT NULL,
         price numeric );
```

Unique Constraints

Unique constraints ensure that the data contained in a column or a group of columns is unique with respect to all the rows in the table. The table must be hash-distributed or replicated (not `DISTRIBUTED RANDOMLY`). If the table is hash-distributed, the constraint columns must be the same as (or a superset of) the table's distribution key columns. For example:

```
=> CREATE TABLE products
       ( `product_no` integer `UNIQUE`,
         name text,
         price numeric)
`      DISTRIBUTED BY (``product_no``)`;
```

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Primary Keys

A primary key constraint is a combination of a `UNIQUE` constraint and a `NOT NULL` constraint. The table must be hash-distributed (not `DISTRIBUTED RANDOMLY`), and the primary key columns must be the same as (or a superset of) the table's distribution key columns. If a table has a primary key, this column (or group of columns) is chosen as the distribution key for the table by default. For example:

```
=> CREATE TABLE products
       ( `product_no` integer `PRIMARY KEY`,
         name text,
         price numeric)
`      DISTRIBUTED BY (``product_no``)`;
```

Foreign Keys

Foreign keys are not supported. You can declare them, but referential integrity is not enforced.

Foreign key constraints specify that the values in a column or a group of columns must match the values appearing in some row of another table to maintain referential integrity between two related tables. Referential integrity checks cannot be enforced between the distributed table segments of a WarehousePG.

Exclusion Constraints

Exclusion constraints ensure that if any two rows are compared on the specified columns or expressions using the specified operators, at least one of these operator comparisons will return false or null. The syntax is:

```
CREATE TABLE circles
(
    c
circle,
    EXCLUDE USING gist (c WITH
&&)
) DISTRIBUTED
REPLICATED;
```

Similar to unique constraints, an exclusion constraint is permitted only for replicated tables or when the distribution key columns are part of the constraint, with the same `=` operator as in the distribution key's hash operator class.

Exclusion constraints are not supported for partitioned tables.

See also CREATE TABLE ... CONSTRAINT ... EXCLUDE for details.

Adding an exclusion constraint automatically creates an index of the type specified in the constraint declaration.

Choosing the Table Distribution Policy

All WarehousePG tables are distributed. When you create or alter a table, you optionally specify `DISTRIBUTED BY` (hash distribution), `DISTRIBUTED RANDOMLY` (random distribution), `DISTRIBUTED REPLICATED` (fully distributed), or `DISTRIBUTED COORDINATOR ONLY` (local to coordinator) to determine the table row distribution.

> **Note** The WarehousePG server configuration parameter `gp_create_table_random_default_distribution` controls the table distribution policy if the DISTRIBUTED BY clause is not specified when you create a table.

For information about the parameter, see "Server Configuration Parameters" of the *WarehousePG Reference Guide*.

Consider the following points when deciding on a table distribution policy.

- **Even Data Distribution** — For the best possible performance, all segments should contain equal portions of data. If the data is unbalanced or skewed, the segments with more data must work harder to perform their portion of the query processing. Choose a distribution key that is unique for each record, such as the primary key.
- **Local and Distributed Operations** — Local operations are faster than distributed operations. Query processing is fastest if the work associated with join, sort, or aggregation operations is done locally, at the segment level. Work done at the system level requires distributing tuples across the segments, which is less efficient. When tables share a common distribution key, the work of joining or sorting on their shared distribution key columns is done locally. With a random distribution policy, local join operations are not an option.
- **Even Query Processing** — For best performance, all segments should handle an equal share of the query workload. Query workload can be skewed if a table's data distribution policy and the query predicates are not well matched. For example, suppose that a sales transactions table is distributed on the customer ID column (the distribution key). If a predicate in a query references a single customer ID, the query processing work is concentrated on just one segment.

The primary use cases for replicated tables are to:

- remove restrictions on operations that user-defined functions can perform on segments, and
- improve query performance by making it unnecessary to broadcast frequently used tables to all segments.

The replicated table distribution policy (`DISTRIBUTED REPLICATED`) should be used only for small tables. Replicating data to every segment is costly in both storage and maintenance, and prohibitive for large fact tables.

The coordinator-only table distribution policy (`DISTRIBUTED COORDINATOR ONLY`) stores data exclusively on the coordinator node. This is a specialized policy intended for small lookup tables or metadata that must be consulted during the planning phase of query processing, before distributed execution begins.

> **Note** The hidden system columns (`ctid`, `cmin`, `cmax`, `xmin`, `xmax`, and `gp_segment_id`) cannot be referenced in user queries on replicated tables because they have no single, unambiguous value. WarehousePG returns a `column does not exist` error for the query.

Declaring Distribution Keys

`CREATE TABLE`'s optional clauses `DISTRIBUTED BY`, `DISTRIBUTED RANDOMLY`, `DISTRIBUTED REPLICATED`, and `DISTRIBUTED COORDINATOR ONLY` specify the distribution policy for a table. The default is a hash distribution policy that uses either the `PRIMARY KEY` (if the table has one) or the first column of the table as the distribution key. Columns with geometric or user-defined data types are not eligible as WarehousePG distribution key columns. If a table does not have an eligible column, WarehousePG distributes the rows randomly.

Replicated tables have no distribution key because every row is distributed to every WarehousePG segment instance.

Coordinator-only tables have no distribution key because every row is on the coordinator only.

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To ensure even distribution of hash-distributed data, choose a distribution key that is unique for each record. If that is not possible, choose `DISTRIBUTED RANDOMLY`. For example:

```
=> CREATE TABLE products
`                        (name varchar(40),
                         prod_id integer,
                         supplier_id integer)
             DISTRIBUTED BY (prod_id);
`
```

```
=> CREATE TABLE random_stuff
`                        (things text,
                         doodads text,
                         etc text)
             DISTRIBUTED RANDOMLY;
`
```

> **Important** If a primary key exists, it is the default distribution key for the table. If no primary key exists, but a unique key exists, this is the default distribution key for the table.

Custom Distribution Key Hash Functions

The hash function used for hash distribution policy is defined by the hash operator class for the column's data type. As the default WarehousePG uses the data type's default hash operator class, the same operator class used for hash joins and hash aggregates, which is suitable for most use cases. However, you can declare a non-default hash operator class in the `DISTRIBUTED BY` clause.

Using a custom hash operator class can be useful to support co-located joins on a different operator than the default equality operator (`=`).

Example Custom Hash Operator Class

This example creates a custom hash operator class for the integer data type that is used to improve query performance. The operator class compares the absolute values of integers.

Create a function and an equality operator that returns true if the absolute values of two integers are equal.

```
CREATE FUNCTION abseq(int, int) RETURNS BOOL AS
$$
  begin return abs($1) = abs($2); end;
$$ LANGUAGE plpgsql STRICT IMMUTABLE;

CREATE OPERATOR |=| (
  PROCEDURE = abseq,
  LEFTARG = int,
  RIGHTARG = int,
  COMMUTATOR = |=|,
  hashes, merges);
```

Now, create a hash function and operator class that uses the operator.

```
CREATE FUNCTION abshashfunc(int) RETURNS int AS
$$
  begin return hashint4(abs($1)); end;
$$ LANGUAGE plpgsql STRICT IMMUTABLE;

CREATE OPERATOR CLASS abs_int_hash_ops FOR TYPE int4
  USING hash AS
  OPERATOR 1 |=|,
  FUNCTION 1 abshashfunc(int);
```

Also, create less than and greater than operators, and a btree operator class for them. We don't need them for our queries, but the Postgres-based planner will not consider co-location of joins without them.

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```
CREATE FUNCTION abslt(int, int) RETURNS BOOL AS
$$
  begin return abs($1) < abs($2); end;
$$ LANGUAGE plpgsql STRICT IMMUTABLE;

CREATE OPERATOR |<| (
  PROCEDURE = abslt,
  LEFTARG = int,
  RIGHTARG = int);

CREATE FUNCTION absgt(int, int) RETURNS BOOL AS
$$
  begin return abs($1) > abs($2); end;
$$ LANGUAGE plpgsql STRICT IMMUTABLE;

CREATE OPERATOR |>| (
  PROCEDURE = absgt,
  LEFTARG = int,
  RIGHTARG = int);

CREATE FUNCTION abscmp(int, int) RETURNS int AS
$$
  begin return btint4cmp(abs($1),abs($2)); end;
$$ LANGUAGE plpgsql STRICT IMMUTABLE;

CREATE OPERATOR CLASS abs_int_btree_ops FOR TYPE int4
  USING btree AS
  OPERATOR 1 |<|,
  OPERATOR 3 |=|,
  OPERATOR 5 |>|,
  FUNCTION 1 abscmp(int, int);
```

Now, you can use the custom hash operator class in tables.

```
CREATE TABLE atab (a int) DISTRIBUTED BY (a abs_int_hash_ops);
CREATE TABLE btab (b int) DISTRIBUTED BY (b abs_int_hash_ops);

INSERT INTO atab VALUES (-1), (0), (1);
INSERT INTO btab VALUES (-1), (0), (1), (2);
```

Queries that perform a join that use the custom equality operator `|=|` can take advantage of the co-location.

With the default integer opclass, this query requires Redistribute Motion nodes.

```
EXPLAIN (COSTS OFF) SELECT a, b FROM atab, btab WHERE a = b;
                           QUERY PLAN
-----------------------------------------------------------------
 Gather Motion 4:1  (slice3; segments: 4)
   ->  Hash Join
         Hash Cond: (atab.a = btab.b)
         ->  Redistribute Motion 4:4  (slice1; segments: 4)
               Hash Key: atab.a
               ->  Seq Scan on atab
         ->  Hash
               ->  Redistribute Motion 4:4  (slice2; segments: 4)
                     Hash Key: btab.b
                     ->  Seq Scan on btab
 Optimizer: Postgres-based planner
(11 rows)
```

With the custom opclass, a more efficient plan is possible.

```
EXPLAIN (COSTS OFF) SELECT a, b FROM atab, btab WHERE a |=| b;
                           QUERY PLAN
-----------------------------------------------------------------
  Gather Motion 4:1  (slice1; segments: 4)
   ->  Hash Join
         Hash Cond: (atab.a |=| btab.b)
         ->  Seq Scan on atab
         ->  Hash
               ->  Seq Scan on btab
 Optimizer: Postgres-based planner
(7 rows)
```

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4.4.6 Choosing the Table Storage Model

WarehousePG supports several storage models and a mix of storage models. When you create a table, you choose how to store its data. This topic explains the options for table storage and how to choose the best storage model for your workload.

- Heap Storage
- Append-Optimized Storage
- Choosing Row or Column-Oriented Storage
- Using Compression (Append-Optimized Tables Only)
- Checking the Compression and Distribution of an Append-Optimized Table
- Altering a Table
- Dropping a Table

> **Note** To simplify the creation of database tables, you can specify the default values for some table storage options with the WarehousePG server configuration parameter `gp_default_storage_options`.

For information about the parameter, see "Server Configuration Parameters" in the *WarehousePG Reference Guide*.

Parent topic: DDL: Defining Database Objects

Heap Storage

By default, WarehousePG uses the same heap storage model as PostgreSQL. Heap table storage works best with OLTP-type workloads where the data is often modified after it is initially loaded. `UPDATE` and `DELETE` operations require storing row-level versioning information to ensure reliable database transaction processing. Heap tables are best suited for smaller tables, such as dimension tables, that are often updated after they are initially loaded.

Append-Optimized Storage

Append-optimized table storage works best with denormalized fact tables in a data warehouse environment. Denormalized fact tables are typically the largest tables in the system. Fact tables are usually loaded in batches and accessed by read-only queries. Moving large fact tables to an append-optimized storage model eliminates the storage overhead of the per-row update visibility information, saving about 20 bytes per row. This allows for a leaner and easier-to-optimize page structure. The storage model of append-optimized tables is optimized for bulk data loading. Single row `INSERT` statements are not recommended.

To create a heap table

Row-oriented heap tables are the default storage type.

```
=> CREATE TABLE foo (a int, b text) DISTRIBUTED BY (a);
```

Use the `WITH` clause of the `CREATE TABLE` command to declare the table storage options. The default is to create the table as a regular row-oriented heap-storage table. For example, to create an append-optimized table with no compression:

```
=> CREATE TABLE bar (a int, b text)
    WITH (appendoptimized=true)
    DISTRIBUTED BY (a);
```

> **Note** You use the `appendoptimized=value` syntax to specify the append-optimized table storage type. `appendoptimized` is a thin alias for the `appendonly` legacy storage option. WarehousePG stores `appendonly` in the catalog, and displays the same when listing storage options for append-optimized tables.

`UPDATE` and `DELETE` are not allowed on append-optimized tables in a repeatable read or serizalizable transaction and will cause the transaction to end prematurely `DECLARE...FOR UPDATE` and triggers are not supported with append-optimized tables. `CLUSTER` on append-optimized tables is only supported over B-tree indexes.

Choosing Row or Column-Oriented Storage

WarehousePG provides a choice of storage orientation models: row, column, or a combination of both. This topic provides general guidelines for choosing the optimum storage orientation for a table. Evaluate performance using your own data and query workloads.

- Row-oriented storage: good for OLTP types of workloads with many iterative transactions and many columns of a single row needed all at once, so retrieving is efficient.
- Column-oriented storage: good for data warehouse workloads with aggregations of data computed over a small number of columns, or for single columns that require regular updates without modifying other column data.

For most general purpose or mixed workloads, row-oriented storage offers the best combination of flexibility and performance. However, there are use cases where a column-oriented storage model provides more efficient I/O and storage. Consider the following requirements when deciding on the storage orientation model for a table:

- **Updates of table data.** If you load and update the table data frequently, choose a row-orientedheap table. Column-oriented table storage is only available on append-optimized tables.

  See Heap Storage for more information.

- **Frequent INSERTs.** If rows are frequently inserted into the table, consider a row-oriented model. Column-oriented tables are not optimized for write operations, as column values for a row must be written to different places on disk.

- **Number of columns requested in queries.** If you typically request all or the majority of columns in the `SELECT` list or `WHERE` clause of your queries, consider a row-oriented model. Column-oriented tables are best suited to queries that aggregate many values of a single column where the `WHERE` or `HAVING` predicate is also on the aggregate column. For example:

  ```
  SELECT SUM(salary)...
  ```

  ```
  SELECT AVG(salary)... WHERE salary > 10000
  ```

  Or where the `WHERE` predicate is on a single column and returns a relatively small number of rows. For example:

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```
SELECT salary, dept ... WHERE state='CA'
```

- **Number of columns in the table.** Row-oriented storage is more efficient when many columns are required at the same time, or when the row-size of a table is relatively small. Column-oriented tables can offer better query performance on tables with many columns where you access a small subset of columns in your queries.
- **Compression.** Column data has the same data type, so storage size optimizations are available in column-oriented data that are not available in row-oriented data. For example, many compression schemes use the similarity of adjacent data to compress. However, the greater adjacent compression achieved, the more difficult random access can become, as data must be uncompressed to be read.

To create a column-oriented table

The `WITH` clause of the `CREATE TABLE` command specifies the table's storage options. The default is a row-orientedheap table. Tables that use column-oriented storage must be append-optimized tables. For example, to create a column-oriented table:

```
=> CREATE TABLE bar (a int, b text)
    WITH (appendoptimized=true, orientation=column)
    DISTRIBUTED BY (a);
```

Using Compression (Append-Optimized Tables Only)

There are two types of in-database compression available in the WarehousePG for append-optimized tables:

- Table-level compression is applied to an entire table.
- Column-level compression is applied to a specific column. You can apply different column-level compression algorithms to different columns.

The following table summarizes the available compression algorithms.

Table Orientation	Available Compression Types	Supported Algorithms
Row	Table	`ZLIB` and `ZSTD`
Column	Column and Table	`RLE_TYPE`, `ZLIB`, and `ZSTD`

When choosing a compression type and level for append-optimized tables, consider these factors:

- CPU usage. Your segment systems must have the available CPU power to compress and uncompress the data.
- Compression ratio/disk size. Minimizing disk size is one factor, but also consider the time and CPU capacity required to compress and scan data. Find the optimal settings for efficiently compressing data without causing excessively long compression times or slow scan rates.
- Speed of compression. Higher compression levels can yield different compression ratios (always at the cost of speed). This varies by compression type: `ZLIB` versus `ZTSD`.
- Speed of decompression/scan rate. Performance with compressed append-optimized tables depends on hardware, query tuning settings, and other factors. Perform comparison testing to determine the actual performance in your environment.

> **Note** Do not create compressed append-optimized tables on file systems that use compression. If the file system on which your segment data directory resides is a compressed file system, your append-optimized table must not use compression.

Performance with compressed append-optimized tables depends on hardware, query tuning settings, and other factors. You should perform comparison testing to determine the actual performance in your environment.

> **Note** `ZTSD` compression level can be set to values between 1 and 19. Compression level with `ZLIB` can be set to values from 1 - 9. Compression level with `RLE` can be set to values from 1 - 4.

An `ENCODING` clause specifies compression type and level for individual columns. When an `ENCODING` clause conflicts with a `WITH` clause, the `ENCODING` clause has higher precedence than the `WITH` clause.

To create a compressed table

The `WITH` clause of the `CREATE TABLE` command declares the table storage options. Tables that use compression must be append-optimized tables. For example, to create an append-optimized table with zlib compression at a compression level of 5:

```
=> CREATE TABLE foo (a int, b text)
   WITH (appendoptimized=true, compresstype=zlib, compresslevel=5);
```

Checking the Compression and Distribution of an Append-Optimized Table

WarehousePG provides built-in functions to check the compression ratio and the distribution of an append-optimized table. The functions take either the object ID or a table name. You can qualify the table name with a schema name.

Table 2. Functions for compressed append-optimized table metadata

Function	Return Type	Description
get_ao_distribution(name) get_ao_distribution(oid)	Set of (dbid, tuplecount) rows	Shows the distribution of an append-optimized table's rows across the array. Returns a set of rows, each of which includes a segment *dbid* and the number of tuples stored on the segment.
get_ao_compression_ratio(name) get_ao_compression_ratio(oid)	float8	Calculates the compression ratio for a compressed append-optimized table. If information is not available, this function returns a value of -1.

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The compression ratio is returned as a common ratio. For example, a returned value of `3.19`, or `3.19:1`, means that the uncompressed table is slightly larger than three times the size of the compressed table.

The distribution of the table is returned as a set of rows that indicate how many tuples are stored on each segment. For example, in a system with four primary segments with*dbid* values ranging from 0 - 3, the function returns four rows similar to the following:

```
=# SELECT get_ao_distribution('lineitem_comp');
 get_ao_distribution
---------------------
(0,7500721)
(1,7501365)
(2,7499978)
(3,7497731)
(4 rows)
```

Support for Run-length Encoding

WarehousePG supports Run-length Encoding (RLE) for column-level compression. RLE data compression stores repeated data as a single data value and a count. For example, in a table with two columns, a date and a description, that contains 200,000 entries containing the value `date1` and 400,000 entries containing the value `date2`, RLE compression for the date field is similar to `date1 200000 date2 400000`. RLE is not useful with files that do not have large sets of repeated data as it can greatly increase the file size.

There are four levels of RLE compression available. The levels progressively increase the compression ratio, but decrease the compression speed.

WarehousePG versions 4.2.1 and later support column-oriented RLE compression. To back up a table with RLE compression that you intend to restore to an earlier version of WarehousePG, alter the table to have no compression or a compression type supported in the earlier version before you start the backup operation.

WarehousePG combines delta compression with RLE compression for data in columns of type `BIGINT`, `INTEGER`, `DATE`, `TIME`, or `TIMESTAMP`. The delta compression algorithm is based on the change between consecutive column values and is designed to improve compression when data is loaded in sorted order or when the compression is applied to data in sorted order.

Adding Column-level Compression

You can add the following storage parameters to a column for append-optimized tables with column orientation:

- Compression type
- Compression level
- Block size for a column

Add storage parameters using the `CREATE TABLE`, `ALTER TABLE`, and `CREATE TYPE` commands.

The following table details the types of storage parameters and possible values for each.

Table 3. Storage Parameters for Column-level Compression

Name	Definition	Values	Comment
`compresstype`	Type of compression.	`zstd:` Zstandard algorithm `zlib:` deflate algorithm `RLE_TYPE`: run-length encoding `none`: no compression	Values are not case-sensitive.
`compresslevel`	Compression level.	`zlib` compression: `1` - `9`	`1` is the fastest method with the least compression. `1` is the default. `9` is the slowest method with the most compression.
		`zstd` compression: `1` - `19`	`1` is the fastest method with the least compression. `1` is the default. `19` is the slowest method with the most compression.

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Name	Definition	Values	Comment		
		`RLE_TYPE` compression: `1` - `6` `1` - apply RLE only `2` - apply RLE then apply zlib compression level 1 `3` - apply RLE then apply zlib compression level 5 `4` - apply RLE then apply zlib compression level 9 `5` - apply RLE then apply zstd compression level 1 `6` - apply RLE then apply zstd compression level 3	`1` is the fastest method with the least compression. `1` is the default method. Within each compression sub-type (RLE with zlib or RLE with zstd), higher compression levels yield higher compression ratios at the cost of speed. Since zstd outperforms zlib in terms of compression ratios and speed, we highly recommend using levels 5 or above.		
		`blocksize`	The size in bytes for each block in the table	`8192 - 2097152`	The value must be a multiple of 8192.

The following is the format for adding storage parameters.

```
[ ENCODING ( <storage_parameter [,…] ) ]
```

where the word ENCODING is required and the storage parameter has three parts:

- The name of the parameter
- An equals sign
- The specification

Separate multiple storage parameters with a comma. Apply a storage parameter to a single column or designate it as the default for all columns, as shown in the following `CREATE TABLE` clauses.

General Usage:

```
<column_name> <data_type> ENCODING ( <storage_directive> [, … ] ), …
```

```
COLUMN <column_name> ENCODING ( <storage_directive> [, … ] ), …
```

```
DEFAULT COLUMN ENCODING ( <storage_directive> [, … ] )
```

Example:

```
C1 char ENCODING (compresstype=zstd, blocksize=65536)
```

```
COLUMN C1 ENCODING (compresstype=zlib, compresslevel=6, blocksize=65536)
```

```
DEFAULT COLUMN ENCODING (compresstype=zlib)
```

Default Compression Values

If the compression type, compression level and block size are not defined, the default is no compression, and the block size is set to the Server Configuration Parameter `block_size`.

Precedence of Compression Settings

Column compression settings are inherited from the type level to the table level to the partition level to the sub-partition level. The lowest-level settings have priority.

- Column compression settings defined at the table level override any compression settings for the type.
- Column compression settings specified at the table level override any compression settings for the entire table.
- Column compression settings specified for partitions override any compression settings at the column or table levels.
- Column compression settings specified for sub-partitions override any compression settings at the partition, column or table levels.
- When an `ENCODING` clause conflicts with a `WITH` clause, the `ENCODING` clause has higher precedence than the `WITH` clause.

> **Note** The `INHERITS` clause is not allowed in a table that contains a storage parameter or a column reference storage parameter.

Tables created using the `LIKE` clause ignore storage parameter and column reference storage parameters.

Optimal Location for Column Compression Settings

The best practice is to set the column compression settings at the level where the data resides. See Example 5, which shows a table with a partition depth of 2. `RLE_TYPE` compression is added to a column at the sub-partition level.

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Storage Parameters Examples

The following examples show the use of storage parameters in `CREATE TABLE` statements.

Example 1

In this example, column `c1` is compressed using `zstd` and uses the block size defined by the system. Column `c2` is compressed with `zlib`, and uses a block size of `65536`. Column `c3` is not compressed and uses the block size defined by the system.

```
CREATE TABLE T1 (c1 int ENCODING (compresstype=zstd),
                 c2 char ENCODING (compresstype=zlib, blocksize=65536),
                 c3 char)    WITH (appendoptimized=true, orientation=column);
```

Example 2

In this example, column `c1` is compressed using `zlib` and uses the block size defined by the system. Column `c2` is compressed with `zstd`, and uses a block size of `65536`. Column `c3` is compressed using `RLE_TYPE` and uses the block size defined by the system.

```
CREATE TABLE T2 (c1 int ENCODING (compresstype=zlib),
                 c2 char ENCODING (compresstype=zstd, blocksize=65536),
                 c3 char,
                 COLUMN c3 ENCODING (compresstype=RLE_TYPE)
                 )
    WITH (appendoptimized=true, orientation=column);
```

Example 3

In this example, column `c1` is compressed using `zlib` and uses the block size defined by the system. Column `c2` is compressed with `zstd`, and uses a block size of `65536`. Column `c3` is compressed using `zlib` and uses the block size defined by the system. Note that column `c3` uses `zlib` (not `RLE_TYPE`) in the partitions, because the column storage in the partition clause has precedence over the storage parameter in the column definition for the table.

```
CREATE TABLE T3 (c1 int ENCODING (compresstype=zlib),
                 c2 char ENCODING (compresstype=zstd, blocksize=65536),
                 c3 text, COLUMN c3 ENCODING (compresstype=RLE_TYPE) )
    WITH (appendoptimized=true, orientation=column)
    PARTITION BY RANGE (c3) (START ('1900-01-01'::DATE)
                             END ('2100-12-31'::DATE),
                             COLUMN c3 ENCODING (compresstype=zlib));
```

Example 4

In this example, `CREATE TABLE` assigns the `zlib` `compresstype` storage parameter to `c1`. Column `c2` has no storage parameter and inherits the compression type (`zstd`) and block size (`65536`) from the `DEFAULT COLUMN ENCODING` clause.

Column `c3`'s `ENCODING` clause defines its compression type, `RLE_TYPE`. The `ENCODING` clause defined for a specific column overrides the `DEFAULT ENCODING` clause, so column `c3` uses the default block size, `32768`.

Column `c4` has a compress type of `none` and uses the default block size.

```
CREATE TABLE T4 (c1 int ENCODING (compresstype=zlib),
                 c2 char,
                 c3 text,
                 c4 smallint ENCODING (compresstype=none),
                 DEFAULT COLUMN ENCODING (compresstype=zstd,
                                          blocksize=65536),
                 COLUMN c3 ENCODING (compresstype=RLE_TYPE)
                 )
   WITH (appendoptimized=true, orientation=column);
```

Example 5

This example creates an append-optimized, column-oriented table, T5. T5 has two partitions, `p1` and `p2`, each of which has sub-partitions. Each sub-partition has `ENCODING` clauses:

- The `ENCODING` clause for partition `p1`'s sub-partition `sp1` defines column `i`'s compression type as `zlib` and block size as 65536.
- The `ENCODING` clauses for partition `p2`'s sub-partition `sp1` defines column `i`'s compression type as `rle_type` and block size is the default value. Column `k` uses the default compression and its block size is 8192.

```
CREATE TABLE T5(i int, j int, k int, l int)
    WITH (appendoptimized=true, orientation=column)
    PARTITION BY range(i) SUBPARTITION BY range(j)
    (
       partition p1 start(1) end(2)
       ( subpartition sp1 start(1) end(2)
         column i encoding(compresstype=zlib, blocksize=65536)
       ),
       partition p2 start(2) end(3)
       ( subpartition sp1 start(1) end(2)
           column i encoding(compresstype=rle_type)
           column k encoding(blocksize=8192)
       )
    );
```

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For an example showing how to add a compressed column to an existing table with the `ALTER TABLE` command, see Adding a Compressed Column to Table.

Adding Compression in a TYPE Command

When you create a new type, you can define default compression attributes for the type. For example, the following `CREATE TYPE` command defines a type named `int33` that specifies `zlib` compression.

First, you must define the input and output functions for the new type, `int33_in` and `int33_out`:

```
CREATE FUNCTION int33_in(cstring) RETURNS int33
  STRICT IMMUTABLE LANGUAGE internal AS 'int4in';
CREATE FUNCTION int33_out(int33) RETURNS cstring
  STRICT IMMUTABLE LANGUAGE internal AS 'int4out';
```

Next, you define the type named `int33`:

```
CREATE TYPE int33 (
   internallength = 4,
   input = int33_in,
   output = int33_out,
   alignment = int4,
   default = 123,
   passedbyvalue,
   compresstype="zlib",
   blocksize=65536,
   compresslevel=1
   );
```

When you specify `int33` as a column type in a `CREATE TABLE` command, the column is created with the storage parameters you specified for the type:

```
CREATE TABLE t2 (c1 int33)
    WITH (appendoptimized=true, orientation=column);
```

Table- or column- level storage attributes that you specify in a table definition override type-level storage attributes. For information about creating and adding compression attributes to a type, seeCREATE TYPE. For information about changing compression specifications in a type, see ALTER TYPE.

Choosing Block Size

The blocksize is the size, in bytes, for each block in a table. Block sizes must be between 8192 and 2097152 bytes, and be a multiple of 8192. The default is 32768.

Specifying large block sizes can consume large amounts of memory. Block size determines buffering in the storage layer. WarehousePG maintains a buffer per partition, and per column in column-oriented tables. Tables with many partitions or columns consume large amounts of memory.

Altering a Table

The `ALTER TABLE` command changes the definition of a table. Use `ALTER TABLE` to change table attributes such as column definitions, distribution policy, access method, storage parameters, and partition structure (see also Partitioning Large Tables). For example, to add a not-null constraint to a table column:

```
=> ALTER TABLE address ALTER COLUMN street SET NOT NULL;
```

Altering Table Distribution

`ALTER TABLE` provides options to change a table's distribution policy. When the table distribution options change, the table data may be redistributed on disk, which can be resource intensive. You can also redistribute table data using the existing distribution policy.

Changing the Distribution Policy

For partitioned tables, changes to the distribution policy apply recursively to the child partitions. This operation preserves the ownership and all other attributes of the table. For example, the following command redistributes the table sales across all segments using the customer_id column as the distribution key:

```
ALTER TABLE sales SET DISTRIBUTED BY (customer_id);
```

When you change the hash distribution of a table, table data is automatically redistributed. Changing the distribution policy to a random distribution does not cause the data to be redistributed. For example, the following `ALTER TABLE` command has no immediate effect:

```
ALTER TABLE sales SET DISTRIBUTED RANDOMLY;
```

Changing the distribution policy of a table to `DISTRIBUTED REPLICATED` or from `DISTRIBUTED REPLICATED` automatically redistributes the table data.

Redistributing Table Data

To redistribute table data for tables with a random distribution policy (or when the hash distribution policy has not changed) use `REORGANIZE=TRUE`. Reorganizing data may be necessary to correct a data skew problem, or when segment resources are added to the system. For example, the following command redistributes table data across all segments using the current distribution policy, including random distribution.

```
ALTER TABLE sales SET WITH (REORGANIZE=TRUE);
```

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Changing the distribution policy of a table to `DISTRIBUTED REPLICATED` or from `DISTRIBUTED REPLICATED` always redistributes the table data, even when you use `REORGANIZE=FALSE`.

Altering the Table Access Method

You may alter the method for accessing a table using the `SET ACCESS METHOD` clause. Set to `heap` to alter the table to be a heap-storage table, `ao_row` to alter the table to be append-optimized with row-oriented storage (AO), or `ao_column` to alter the table to be append-optimized with column-oriented storage (AOCO).

> **Note: Note:** Although you can specify the table's access method using `SET <storage_parameter>` or `SET WITH<storage_parameter>`, WarehousePG recommends that you use `SET ACCESS METHOD <access_method>` instead.

Altering the Table Storage Model

You may dynamically update a table's storage model -- including whether the table is heap, AO or AOCO; the table's compression and blocksize settings; and the table's fillfactor; -- by setting a variety of storage parameters when you invoke `ALTER TABLE` with the `SET <storage_parameter>` clause. This is true for both regular tables and partitioned tables.

Inheritance Rules for Altering a Partitioned Table's Storage Model

The following inheritance rules apply to the storage model of a partitioned table:

- Altering the storage model at the partition root changes the storage model for all existing children and all future children.
- Altering the storage model at the partition root with the `ONLY` keyword changes the storage model only for all future children.
- Altering the storage model at a leaf changes the storage model only for that leaf.

Adding a Compressed Column to Table

Use `ALTER TABLE` command to add a compressed column to a table. All of the options and constraints for compressed columns described in Adding Column-level Compression apply to columns added with the `ALTER TABLE` command.

The following example shows how to add a column with `zlib` compression to a table, `T1`.

```
ALTER TABLE T1
      ADD COLUMN c4 int DEFAULT 0
      ENCODING (compresstype=zlib);
```

Inheritance of Compression Settings

A partition added to a table that has sub-partitions defined with compression settings inherits the compression settings from the sub-partition. The following example shows how to create a table with sub-partition encodings, then alter it to add a partition.

```
CREATE TABLE ccddl (i int, j int, k int, l int)
  WITH
    (appendoptimized = TRUE, orientation=COLUMN)
  PARTITION BY range(j)
  SUBPARTITION BY list (k)
  SUBPARTITION template(
    SUBPARTITION sp1 values(1, 2, 3, 4, 5),
    COLUMN i ENCODING(compresstype=ZLIB),
    COLUMN j ENCODING(compresstype=ZLIB),
    COLUMN k ENCODING(compresstype=ZLIB),
    COLUMN l ENCODING(compresstype=ZLIB))
  (PARTITION p1 START(1) END(10),
   PARTITION p2 START(10) END(20))
;

ALTER TABLE ccddl
  ADD PARTITION p3 START(20) END(30)
;
```

Running the `ALTER TABLE` command creates partitions of table `ccddl` named `ccddl_1_prt_p3` and `ccddl_1_prt_p3_2_prt_sp1`. Partition `ccddl_1_prt_p3` inherits the different compression encodings of sub-partition `sp1`.

Dropping a Table

The `DROP TABLE` command removes tables from the database. For example:

```
DROP TABLE mytable;
```

To empty a table of rows without removing the table definition, use `DELETE` or `TRUNCATE`. For example:

```
DELETE FROM mytable;

TRUNCATE mytable;
```

`DROP TABLE` always removes any indexes, rules, triggers, and constraints that exist for the target table. Specify `CASCADE` to drop a table that is referenced by a view. `CASCADE` removes dependent views.

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4.4.7 Partitioning Large Tables

Table partitioning in WarehousePG enables you to logically divide large tables, such as fact tables, into smaller, more manageable pieces. Partitioning tables can improve query performance when it allows the WarehousePG query optimizer to scan only the data needed to satisfy a given query instead of scanning the complete contents of a large table.

Partitioning does not change the physical distribution of table data across the segments. Table distribution is physical: WarehousePG physically divides partitioned tables and non-partitioned tables across segments to enable parallel query processing. Table *partitioning* is logical: WarehousePG logically divides big tables to improve query performance and facilitate data warehouse maintenance tasks, such as rolling old data out of the data warehouse.

Parent topic: DDL: Defining Database Objects

Why Table Partitioning?

Partitioning can provide several benefits:

- Dramatically improves query performance in certain situations, particularly when most of the heavily accessed rows of the table are in a single partition or a small number of partitions. Partitioning effectively substitutes for the upper tree levels of indexes, making it more likely that the heavily-used parts of the indexes fit in memory.
- When queries or updates access a large percentage of a single partition, you can improve performance by using a sequential scan of that partition instead of using an index, which would require random-access reads scattered across the whole table.
- When the partitioning design accounts for the usage pattern, you can perform bulk loads and deletes by adding or removing partitions. Dropping an individual partition using `DROP TABLE`, or doing `ALTER TABLE DETACH PARTITION`, is far faster than a bulk operation. These commands also entirely prevent the `VACUUM` overhead caused by a bulk `DELETE`.
- You can migrate seldom-used data to cheaper and slower storage media.

These benefits will normally be worthwhile only when a table would otherwise be very large. The exact point at which a table will benefit from partitioning depends on the application, although a rule of thumb is that the size of the table should exceed the physical memory of the database server.

About the Table Partitioning Methods

WarehousePG supports the following forms of table partitioning:

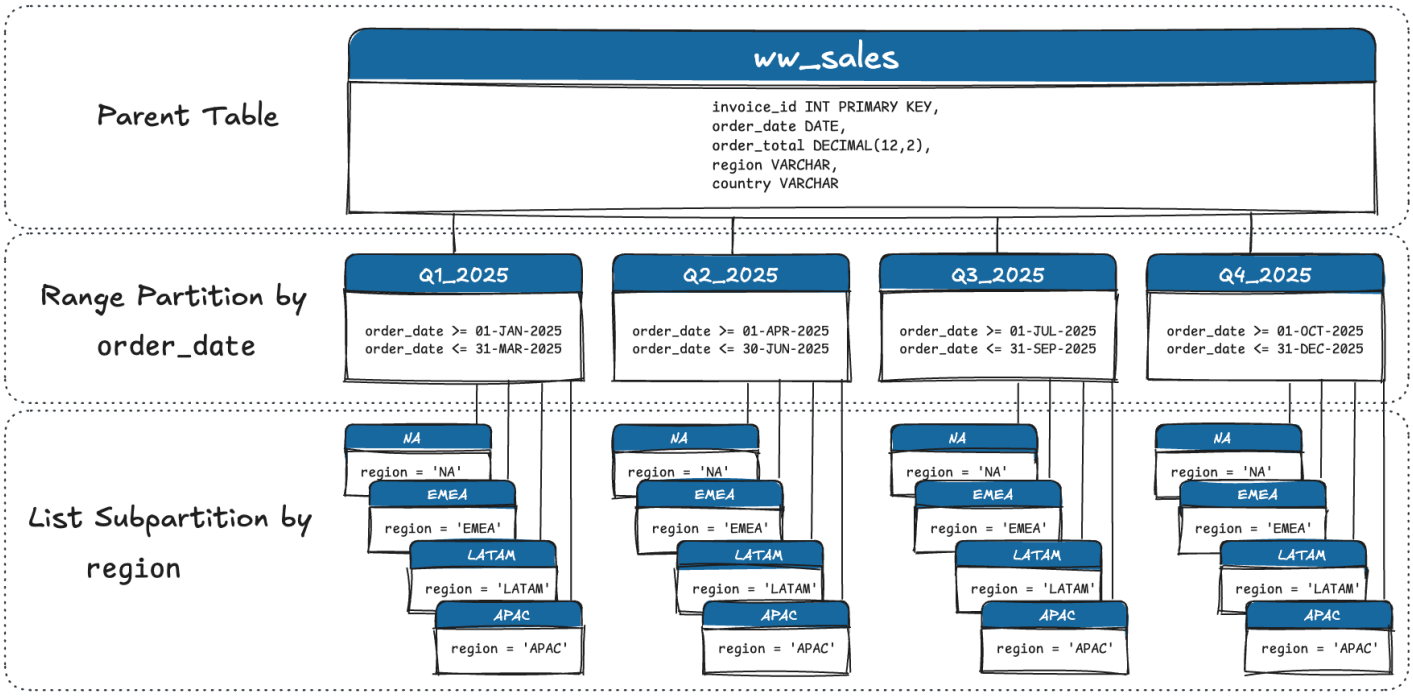
Range Partitioning The table is partitioned into "ranges" defined by a key column or set of columns, with no overlap between the ranges of values assigned to different partitions. For example, one might partition by date ranges, or by ranges of identifiers for particular business objects. Each range's bounds are understood as being inclusive at the lower end and exclusive at the upper end. For example, if one partition's range is from `1` to `10`, and the next one's range is from `10` to `20`, the value `10` belongs to the second partition not the first.

List Partitioning The table is partitioned by explicitly listing which key value(s) appear in each partition, for example sales territory or product line.

Hash Partitioning The table is partitioned by specifying a modulus and a remainder for each partition. Each partition holds the rows for which the hash value of the partition key divided by the specified modulus produces the specified remainder.

The following figure illustrates a multi-level partition design utilizing both date-range and list partitioning.

Multi-Level Partitioning



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About Table Partitioning in WarehousePG

WarehousePG allows you to declare that a table is divided into partitions. The table that is divided is a *partitioned table*. The declaration includes the *partitioning method* as described above, plus a list of columns or expressions to be used as the *partition key*.

The partitioned table itself is a "virtual" table having no storage of its own. Instead, the storage belongs to partitions, which are otherwise ordinary tables associated with the partitioned table. Each partition stores a subset of the data as defined by its *partition bounds*. WarehousePG routes all rows inserted into a partitioned table to the appropriate partitions based on the values of the partition key column(s). WarehousePG will move a row to a different partition if you update the partition key and the key no longer satisfies the partition bounds of its original partition.

You initially partition tables during creation by specifying the `PARTITION BY` or `PARTITION OF` clause to the CREATE TABLE command. When you created a partitioned table, you create a top-level *root partitioned table* with one or more levels of *child* tables. The table at the level immediately above a child table is the *parent*. A table at the highest level in a partition hierarchy is a *leaf partition*. A leaf partition has no child tables, and leaf partitions in the same partition hierarchy may reside at different depths.

WarehousePG uses the partition criteria (boundaries) defined during table creation to create each partition with a distinct partition constraint, which limits the data that table can contain. The query optimizers use partition constraints to determine which table partitions to scan to satisfy a given query predicate.

A partition itself may be defined as a partitioned table, resulting in sub-partitioning. Although all partitions must have the same columns as their partitioned parent, partitions may have their own indexes, constraints, and default values, distinct from those of other partitions. Refer to the CREATE TABLE command reference for more details on creating partitioned tables and partitions.

Each partition's definition must specify bounds that correspond to the partitioning method and partition key of the parent. WarehousePG returns an error if the bounds of a new partition's values overlap with those in one or more existing partitions. Partitions are in every way normal WarehousePG tables (or, possibly, external or foreign tables). You can specify a tablespace and storage parameters for each partition separately.

Because partitions themselves are independent tables, if a table that is part of a partition hierarchy itself is writable, you can write to it through its parent also, as long as granted the correct permission.

You cannot turn a regular table into a partitioned table or vice-versa. However, it is possible to add an existing regular or partitioned table as a partition of a partitioned table, or to remove a partition from a partitioned table turning it into a standalone table; these operations can simplify and speed up many maintenance processes. Refer to the ALTER TABLE command reference to learn more about the syntax for these operations.

While a partition can also be an external table or foreign table, take extra care because it becomes your responsibility to ensure that the contents of the table satisfy the partitioning rule. There are other restrictions for foreign tables as well; refer to the CREATE FOREIGN TABLE command reference for more information.

Deciding on a Table Partitioning Strategy

Not all hash-distributed or randomly distributed tables are good candidates for partitioning. If the answer is **yes** to all or most of the following questions, table partitioning is a viable database design strategy for improving query performance. If the answer is **no** to most of the following questions, table partitioning is not the right solution for that table. Always test your design strategy to ensure that query performance improves as expected.

- **Is the table large enough?** Large fact tables are good candidates for table partitioning. If you have millions or billions of records in a table, you may see performance benefits from logically breaking that data up into smaller chunks. For smaller tables with only a few thousand rows or less, the administrative overhead of maintaining the partitions may outweigh any performance benefits that you might see.
- **Are you experiencing unsatisfactory performance?** As with any performance tuning initiative, a table should be partitioned only if queries against that table are producing slower response times than desired.
- **Do your query predicates have identifiable access patterns?** Examine the `WHERE` clauses of your query workload and look for table columns that are consistently used to access data. For example, if most of your queries tend to look up records by date, then a monthly or weekly date-partitioning design might be beneficial. Or if you tend to access records by region, consider a list-partitioning design to divide the table by region.
- **Does your data warehouse maintain a window of historical data?** Another consideration for partition design is your organization's business requirements for maintaining historical data. For example, your data warehouse may require that you keep data for the past twelve months. If the data is partitioned by month, you can easily drop the oldest monthly partition from the warehouse and load current data into the most recent monthly partition.
- **Can the data be divided into somewhat equal parts based on some defining criteria?** Choose partitioning criteria that will divide your data as evenly as possible. If the partitions contain a relatively equal number of records, query performance improves based on the number of partitions created. For example, by dividing a large table into 10 partitions, a query will run 10 times faster than it would against the unpartitioned table, provided that the partitions are designed to support the query's criteria.

Do not create more partitions than are needed. Creating too many partitions can slow down management and maintenance jobs, such as vacuuming, recovering segments, expanding the cluster, checking disk usage, and others.

Partitioning does not improve query performance unless the query optimizer can eliminate partitions based on the query predicates. Queries that scan every partition run slower than if the table were not partitioned, so avoid partitioning if few of your queries achieve partition elimination. Check the explain plan for queries to make sure that partitions are eliminated. See Query Profiling for more about partition elimination.

> **Caution** Be very careful with multi-level partitioning, as the number of partition files can grow very quickly. For example, if a table is partitioned by both day and city, and there are 1,000 days of data and 1,000 cities, the total number of partitions is one million. Column-oriented tables store each column in a physical table, so if this table has 100 columns, the system would be required to manage 100 million files for the table, for each segment.

Before settling on a multi-level partitioning strategy, consider a single level partition with bitmap indexes. Indexes slow down data loads, so performance testing with your data and schema is recommended to decide on the best strategy.

Choosing the Partitioning Syntax

WarehousePG 7 retains most aspects of the partitioning syntax of prior versions of WarehousePG, referred to as the *classic* syntax. Version 7 also introduces support for a *modern* syntax, derived from the PostgreSQL declarative partitioning syntax.

The classic syntax is provided for backwards compatibility with previous WarehousePG versions. It is appropriate for a homogenous partitioned table, where all partitions are at the same leaf level and have the same partition rule.

> **Note** The modern syntax is less specialized and easier to use, and is recommended for new users and new partitioned table definitions.

The classic and modern partitioning syntaxes are alternatives, you choose the one that meets your needs.

If you are familiar with the WarehousePG 6 partitioning syntax or already have partitioned tables that were defined using this syntax, you may choose to continue using the classic syntax. (Refer to About Changes to Table Partitioning in WarehousePG 7 for more information about partitioning syntax and behavior changes introduced in version 7.)

The following table provides a feature comparison to help you choose the syntax most appropriate for your data model:

Feature	Classic Syntax	Modern Syntax
Heterogeneous partition hierarchy	Not supported. All leaf partitions are at the same level.	Supported. Leaf partitions are permitted at different levels. You can specify different partitioning rules for individual child tables, including different partition columns and different partitioning strategies.
Expressions in partition key	Not supported.	Supported.
Multi-column range partitioning	Not supported.	Supported.
Multi-column list partitioning	Supported (via composite type).	Not supported.
Hash partitioning	Not supported.	Supported.

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Feature	Classic Syntax	Modern Syntax
Adding a Partition	Adding a partition acquires an `ACCESS EXCLUSIVE` lock on the parent table.	Attaching a partition acquires a less restrictive `SHARE UPDATE EXCLUSIVE` lock on the parent table.
Removing a Partition	Dropping a partition deletes the table contents. Must create a dummy table and swap.	Supported. Can directly detach a partition, retaining the table contents.
Sub-partition templating	Supported. The definitions of the parent and child tables are consistent by default.	Not supported. You ensure that the table definitions are consistent.
Partition maintenance	You operate on a child table via the parent, requiring knowledge of the partition hierarchy.	You operate directly on the child table, no knowledge of the partition hierarchy is required.

> **Important** After creation, operate on the partition hierarchy using the `CREATE TABLE` and `ALTER TABLE` clauses identified for the syntax that you chose. WarehousePG does not recommend mixing and matching the classic and modern partitioning syntaxes for partition maintenance operations.

Creating a Partitioned Table

You partition a table when you create it with the CREATE TABLE command. Before you create the table, you should:

1. Choose the partition method: date range, numeric range, list of values, hash.
2. Choose the column(s) on which to partition the table.
3. Determine the appropriate number of partitions and partition levels. For example, you may choose to create a table that is date-range partitioned by month, and then sub-partition the monthly partitions by sales region.
4. Create the partitioned table.
5. Create the partitions.

You are not required to manually create table constraints describing the partition boundary conditions for partitions, WarehousePG creates such constraints automatically.

After you create a partition, WarehousePG directs to the partition any data inserted into the root partitioned table that matches this partition's partition constraints. The partition key specified may overlap with the parent's partition key, although take care when specifying the bounds of a sub-partition such that the set of data it accepts constitutes a subset of what the partition's own bounds allow; WarehousePG does not check whether that's really the case.

You can use the same partition key column to create sub-partitions if necessary, for example, to partition by month and then sub-partition by day. Consider partitioning by the most granular level. For example, for a table partitioned by date, you can partition by day and have 365 daily partitions, rather than partition by year then sub-partition by month then sub-partition by day. A multi-level design can reduce query planning time, but a flat partition design typically runs faster.

> **Important** The examples in the next section use the modern partitioning syntax. Refer to Examples Using the Classic Partitioning Syntax for information about the classic partitioning syntax and parallel examples.

Creating Partitioned Tables with the Modern Syntax

The following subsections provide modern syntax examples for creating tables with various partition designs.

Defining a Date-Range Partitioned Table

A date-range partitioned table uses a `date` or `timestamp` column as the partition key column.

> **Note** The modern partitioning syntax supports specifying multiple partition key columns for range partitioned tables.

Example Requirements: In this example, you construct a database for a large ice cream company. The company measures peak temperatures every day as well as ice cream sales in each region. The main use of the table is to prepare online reports for management, so most queries will access just the last week's, month's, or quarter's data. To reduce the amount of old data that needs to be stored, retain only the most recent 2 years worth of data. At the beginning of each month, remove the oldest month's data.

Create a range-partitioned table named `measurement` that is partitioned on a `logdate` column:

```
CREATE TABLE measurement (
    city_id         int not null,
    logdate         date not null,
    peaktemp        int,
    unitsales       int )
DISTRIBUTED BY (city_id)
PARTITION BY RANGE (logdate);
```

Create partitions. Each partition should hold one month's worth of data, to match the requirement of deleting one month's data at a time.

```
CREATE TABLE measurement_y2021m01 PARTITION OF measurement
  FOR VALUES FROM ('2021-01-01') TO ('2021-02-01');

CREATE TABLE measurement_y2021m02 PARTITION OF measurement
  FOR VALUES FROM ('2021-02-01') TO ('2021-03-01');

CREATE TABLE measurement_y2021m03 PARTITION OF measurement
  FOR VALUES FROM ('2021-03-01') TO ('2021-04-01');

...

CREATE TABLE measurement_y2021m11 PARTITION OF measurement
  FOR VALUES FROM ('2021-11-01') TO ('2021-12-01');

CREATE TABLE measurement_y2022m12 PARTITION OF measurement
  FOR VALUES FROM ('2022-12-01') TO ('2022-01-01')
  TABLESPACE fasttablespace;

CREATE TABLE measurement_y2023m01 PARTITION OF measurement
  FOR VALUES FROM ('2023-01-01') TO ('2023-02-01')
  WITH (parallel_workers = 4)
  TABLESPACE fasttablespace;
```

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Recall that adjacent partitions can share a bound value, since WarehousePG treats range upper bounds as exclusive bounds.

Any data inserted into `measurement` is redirected to the appropriate partition based on the `logdate` column. WarehousePG returns an error when data is inserted into the parent table that does not map to one of the existing partitions.

In this example scenario, a new partition will be created each month. You might write a script that generates the required DDL automatically.

Defining a Numeric-Range Partitioned Table

A numeric-range partitioned table uses a numeric-type column as the partition key column. The modern syntax supports specifying multiple partition key columns for range partitioned tables.

For example, create a numeric-range partitioned table named `numpart` that is partitioned on a `year` column:

```
CREATE TABLE numpart (id int, rank int, year int, color char(1), count int)
  DISTRIBUTED BY (id)
  PARTITION BY RANGE (year);
```

Create the partitions for four years of data:

```
CREATE TABLE numpart_y2019 PARTITION OF numpart FOR VALUES FROM (2019) TO (2020);
CREATE TABLE numpart_y2020 PARTITION OF numpart FOR VALUES FROM (2020) TO (2021);
CREATE TABLE numpart_y2021 PARTITION OF numpart FOR VALUES FROM (2021) TO (2022);
CREATE TABLE numpart_y2022 PARTITION OF numpart FOR VALUES FROM (2022) TO (2023);
```

Defining a List Partitioned Table

A list partitioned table can use any data type column that allows equality comparisons as its partition key column.

> **Note** The modern syntax allows only a single column as the partition key for a list partition.

You must declare a partition specification for every list value that you create.

The following example creates a partitioned table named `listpart` that is list-partitioned on a `color` column:

```
CREATE TABLE listpart (id int, rank int, year int, color char(1), count int)
  DISTRIBUTED BY (id)
  PARTITION BY LIST (color);
```

Create the partitions:

```
CREATE TABLE listpart_red PARTITION OF listpart FOR VALUES IN ('r');
CREATE TABLE listpart_green PARTITION OF listpart FOR VALUES IN ('g');
CREATE TABLE listpart_blue PARTITION OF listpart FOR VALUES IN ('b');
CREATE TABLE listpart_other PARTITION OF listpart DEFAULT;
```

Note that the `listpart_other` table is created with the `DEFAULT` keyword. This identifies the table as the default partition; WarehousePG routes any data that falls outside of the boundaries of all partitions to this table. See Adding a Default Partition for more information.

Defining a Hash Partitioned Table

> **Note** You can create a hash partitioned table only with the modern partitioning syntax.

A hash partitioned table uses a single hashable column as its partition key column. For hash partitions, you must declare a partition specification for every partition (modulus/remainder combination) that you want to create.

For example, create a table named `hpt` that is partitioned by the hash of the `text` column `c`:

```
CREATE TABLE hpt (a int, b int, c text) PARTITION BY HASH(c);
```

Create the partitions:

```
CREATE TABLE hpt_p1 PARTITION OF hpt FOR VALUES WITH (MODULUS 3, REMAINDER 0);
CREATE TABLE hpt_p2 PARTITION OF hpt FOR VALUES WITH (MODULUS 3, REMAINDER 1);
CREATE TABLE hpt_p3 PARTITION OF hpt FOR VALUES WITH (MODULUS 3, REMAINDER 2);
```

Insert some data into the partitioned table, and then display the number of rows in each partition:

```
INSERT INTO hpt SELECT i, i, to_char(i/50, 'FM0000') FROM generate_series(0, 599, 2) i;
SELECT 'hpt_p1' AS partition, count(*) AS row_count FROM hpt_p1
  UNION ALL SELECT 'hpt_p2', count(*) FROM hpt_p2
  UNION ALL SELECT 'hpt_p3', count(*) FROM hpt_p3;
```

Defining a Multi-level Partitioned Table

You can create a multi-level partition hierarchy by sub-partitioning partitions.

The following modern syntax commands create a two-level partition design similar to that shown in the figure at the beginning of this topic.

Create a table named `msales` that is partitioned by year:

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```
CREATE TABLE msales (trans_id int, year int, amount decimal(9,2), region text)
  DISTRIBUTED BY (trans_id)
  PARTITION BY RANGE (year);
```

Create the yearly partitions, which are themselves partitioned by region:

```
CREATE TABLE msales_2021 PARTITION OF msales FOR VALUES FROM (2021) TO (2022)
  PARTITION BY LIST (region);
CREATE TABLE msales_2022 PARTITION OF msales FOR VALUES FROM (2022) TO (2023)
  PARTITION BY LIST (region);
CREATE TABLE msales_2023 PARTITION OF msales FOR VALUES FROM (2023) TO (2024)
  PARTITION BY LIST (region);
```

Create the region partitions:

```
CREATE TABLE msales_2021_usa PARTITION OF msales_2021 FOR VALUES IN ('usa');
CREATE TABLE msales_2021_asia PARTITION OF msales_2021 FOR VALUES IN ('asia');
CREATE TABLE msales_2021_europe PARTITION OF msales_2021 FOR VALUES IN ('europe');
CREATE TABLE msales_2022_usa PARTITION OF msales_2022 FOR VALUES IN ('usa');
CREATE TABLE msales_2022_asia PARTITION OF msales_2022 FOR VALUES IN ('asia');
CREATE TABLE msales_2022_europe PARTITION OF msales_2022 FOR VALUES IN ('europe');
CREATE TABLE msales_2023_usa PARTITION OF msales_2023 FOR VALUES IN ('usa');
CREATE TABLE msales_2023_asia PARTITION OF msales_2023 FOR VALUES IN ('asia');
CREATE TABLE msales_2023_europe PARTITION OF msales_2023 FOR VALUES IN ('europe');
```

Partitioning an Existing Table

Tables can be partitioned only at creation. If you have an existing table that you want to partition, you must create a partitioned table, load the data from the original table to the new table, drop the original table, and rename the new table to the original table name. You must also re-grant any table permissions.

For example:

```
CREATE TABLE msales2 (LIKE msales) PARTITION BY RANGE (year);
-- create the partitions
INSERT INTO msales2 SELECT * FROM msales;
DROP TABLE msales;
ALTER TABLE msales2 RENAME TO msales;
GRANT ALL PRIVILEGES ON msales TO admin;
GRANT SELECT ON msales TO guest;
```

> **Note** The `LIKE` clause does not copy over partition structures when you use it to create a new table.

Loading Data into a Partitioned Table

After you create the partitioned table structure, the top-level root partitioned table is empty. When you insert data into the root, WarehousePG routes the data to the bottom-level leaf partitions. In a multi-level partition design, only the leaf partitions at the bottom-most levels of the hierarchy will contain data.

WarehousePG rejects rows that cannot be mapped to a leaf partition, and the load fails. To avoid rejection of unmapped rows at load time, define your partition hierarchy with a `DEFAULT` partition. Any rows that do not match the partition constraint of all partitions load into the `DEFAULT` partition. Refer to Adding a Default Partition for more information.

At runtime, the query optimizer scans the entire partition hierarchy and uses the partition constraints to determine which of the child partitions to scan to satisfy the query's conditions. Because WarehousePG always scans the `DEFAULT` partition (if your hierarchy has one), `DEFAULT` partitions that contain data can slow down the overall scan time.

When you use `COPY` or `INSERT` to load data into a parent table, WarehousePG automatically routes the data to the correct leaf partition, just as it does with a regular table.

A best practice for loading data into partitioned tables is to create an intermediate staging table, load it, and then attach it into your partition hierarchy. See Adding a Partition.

Verifying the Partition Strategy

When a table is partitioned based on the query predicate, you can use EXPLAIN to verify that the query optimizer scans only the relevant data to examine the query plan.

For example, suppose a table named `msales` is year-range partitioned and sub-partitioned by `region`. For the following query:

```
EXPLAIN SELECT * FROM msales WHERE year='2021' AND region='usa';
```

The query plan for this query should show a table scan of only the following tables:

- the default partition returning 0-1 rows (if your partition design has one)
- the 2021 partition (`msales_2021`) returning 0-1 rows
- the USA region sub-partition (`msales_2021_usa`) returning *some number* of rows.

The following example shows the relevant portion of the query plan.

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```
                                QUERY PLAN
-------------------------------------------------------------------------------
 Gather Motion 3:1  (slice1; segments: 3)  (cost=0.00..228.52 rows=1 width=54)
   ->  Seq Scan on msales_2021_usa  (cost=0.00..228.50 rows=1 width=54)
         Filter: ((year = 2021) AND (region = 'usa'::text))
 Optimizer: Postgres-based planner
(4 rows)
```

Ensure that the query optimizer does not scan unnecessary partitions or sub-partitions (for example, scans of months or regions not specified in the query predicate), and that scans of the top-level tables return 0-1 rows.

Troubleshooting Selective Partition Scanning

The following limitations can result in a query plan that shows a non-selective scan of your partition hierarchy.

- The query optimizer can selectively scan partitioned tables only when the query contains a direct and simple restriction of the table using immutable operators such as: `=`, `<`, `<=`, `>`, `>=`, and `<>`.
- Selective scanning recognizes `STABLE` and `IMMUTABLE` functions, but does not recognize `VOLATILE` functions within a query. For example, `WHERE` clauses such as `date > CURRENT_DATE` cause the query optimizer to selectively scan partitioned tables, but `time > TIMEOFDAY` does not.

About Viewing Your Partition Design

Partitioning information is stored in the pg_partitioned_table system catalog, and in additional fields in thepg_class (`relispartition` and `relpartbound`) catalog.

You can also use the following functions to obtain information about the partitioned tables in the database:

Name	Return Type	Description
pg_partition_tree(regclass)	setof record	Lists information about tables or indexes in a partition hierarchy for a given partitioned table or partitioned index, with one row for each partition. Information provided includes the name of the partition, the name of its immediate parent, a `boolean` value indicating if the partition is a leaf, and an `integer` identifying its level in the hierarchy. The value of level begins at `0` for the input table or index in its role as the root of the partition hierarchy, `1` for its partitions, `2` for their partitions, and so on.
pg_partition_ancestors(regclass)	setof regclass	Lists the ancestor relations of the given partition, including the partition itself.
pg_partition_root(regclass)	regclass	Returns the topmost parent of the partition hierarchy to which the given relation belongs.

For example, the following command displays the partition inheritance structure of the `msales` table:

```
SELECT * FROM pg_partition_tree( 'msales' );
```

Viewing a Classic Syntax Sub-Partition Template

For a partitioned table that you create using the classic syntax, thegp_partition_template system catalog table describes the relationship between the partitioned table and the sub-partition template defined at each level in the partition hierarchy.

Use the `pg_get_expr()` helper function with `gp_partition_template` to get a more user-friendly view of the template, as follows:

```
SELECT pg_get_expr(template, relid) FROM gp_partition_template
  WHERE relid = '<table_name>'::regclass;
```

Constructing a pg_partitions-Equivalent Query

Refer to Migrating Partition Maintenance Scripts to the New WarehousePG 7 Partitioning Catalogs for information about mapping WarehousePG 6 partitioning catalogs to the new definitions in WarehousePG 7.

About Partition Pruning

Partition pruning is a query optimization technique that improves performance for declaratively partitioned tables.

You can enable or disable partition pruning for the Postgres-based planner by setting the enable_partition_pruning server configuration parameter.

As an example:

```
SET enable_partition_pruning = on;                -- the default
SELECT count(*) FROM measurement WHERE logdate >= DATE '2021-01-01';
```

Without partition pruning, the above query would scan each of the partitions of the `measurement` table. With partition pruning enabled, the planner or query optimizer examines the definition of each partition to prove that the partition need not be scanned because it could not contain any rows meeting the query's `WHERE` clause. When the planner or query optimizer can prove this, it excludes (prunes) the partition from the query plan.

Using the `EXPLAIN` command and the `enable_partition_pruning` configuration parameter, it's possible to show the difference between a plan for which partitions have been pruned and one for which they have not. A typical unoptimized plan from the Postgres-based planner for this type of table setup is:

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```
SET enable_partition_pruning = off;
EXPLAIN SELECT count(*) FROM measurement WHERE logdate >= DATE '2021-01-01';

                                  QUERY PLAN
-------------------------------------------------------------------------------
 Aggregate  (cost=188.76..188.77 rows=1 width=8)
   ->  Append  (cost=0.00..181.05 rows=3085 width=0)
         ->  Seq Scan on measurement_y2021m01  (cost=0.00..33.12 rows=617 width=0)
               Filter: (logdate >= '2021-01-01'::date)
         ->  Seq Scan on measurement_y2021m02  (cost=0.00..33.12 rows=617 width=0)
               Filter: (logdate >= '2021-01-01'::date)
...
         ->  Seq Scan on measurement_y2023m01  (cost=0.00..33.12 rows=617 width=0)
               Filter: (logdate >= '2021-01-01'::date)
```

Some or all of the partitions might use index scans instead of full-table sequential scans, but the point is that there is no need to scan the older partitions to answer this query. With partition pruning enabled, a significantly cheaper plan is generated that delivers the same answer:

```
SET enable_partition_pruning = on;
EXPLAIN SELECT count(*) FROM measurement WHERE logdate >= DATE '2008-01-01';

                                  QUERY PLAN
-------------------------------------------------------------------------------
 Aggregate  (cost=37.75..37.76 rows=1 width=8)
   ->  Seq Scan on measurement_y2021m01  (cost=0.00..33.12 rows=617 width=0)
         Filter: (logdate >= '2021-01-01'::date)
```

Note that partition pruning is driven only by the constraints defined implicitly by the partition keys, not by the presence of indexes. Therefore it isn't necessary to define indexes on the key columns. Whether you should create an index for a given partition depends on whether you expect that queries that scan the partition will generally scan a large part of the partition or just a small part. An index will be helpful in the latter case but not the former.

Partition pruning can be performed not only during the planning of a given query, but also during its execution. This is useful because it can allow more partitions to be pruned when clauses contain expressions whose values are not known at query planning time, for example, parameters defined in a `PREPARE` statement, using a value obtained from a subquery, or using a parameterized value on the inner side of a nested loop join. Partition pruning during execution can be performed at any of the following times:

- During initialization of the query plan. Partition pruning can be performed here for parameter values which are known during the initialization phase of execution. Partitions which are pruned during this stage will not show up in the query's `EXPLAIN` or `EXPLAIN ANALYZE`. It is possible to determine the number of partitions which were removed during this phase by observing the "Subplans Removed" property in the `EXPLAIN` output.
- During actual execution of the query plan. Partition pruning may also be performed here to remove partitions using values which are only known when running the actual query. This includes values from subqueries and values from run-time parameters such as those from parameterized nested loop joins. Since the value of these parameters may change many times during the execution of the query, WarehousePG performs partition pruning whenever one of the run-time parameters being used by partition pruning changes. Determining whether partitions were pruned during this phase requires careful inspection of the loops property in the `EXPLAIN ANALYZE` output. Subplans corresponding to different partitions may have different values for it depending on how many times each of them was pruned during execution. Some may be shown as `(never executed)` if they were pruned every time.

Partition Maintenance

Normally, the set of partitions established when initially defining the table is not intended to remain static. Common scenarios include removing partitions holding old data and periodically adding new partitions for new data. One of the biggest advantages of partitioning is precisely that it allows you to perform these tasks nearly instantaneously by manipulating the partition structure, rather than physically moving around large amounts of data.

> **Important** The examples in the next section use the modern partitioning syntax. Refer to Partition Maintenance with the Classic Syntax for information about the maintenance activities and commands for partitioned tables that you created using the classic partitioning syntax.

Partition Maintenance with the Modern Syntax

To maintain a partitioned table that you created with the modern syntax, you use the `ALTER TABLE` command against the top-level root partitioned table or the partition itself.

Adding a Partition

You add a new partition to handle new data. You can add a partition to a partition hierarchy both at the time of, or after, table creation.

To add to the partition hierarchy during table creation, use the `CREATE TABLE ... PARTITION OF` command. For example:

```
CREATE TABLE msales_mfeb20 PARTITION OF msales
    FOR VALUES FROM ('2020-02-01') TO ('2020-03-01');
```

Alternatively, it is sometimes more convenient to create the new table outside of the partition structure, and make it a proper partition later. This allows data to be loaded, checked, and transformed prior to it appearing in a partitioned table. The `CREATE TABLE ... LIKE` command form avoids having to repeat the parent table's definition:

```
-- create like the parent table
CREATE TABLE msales_mfeb20 (LIKE msales INCLUDING DEFAULTS INCLUDING CONSTRAINTS);

-- add constraints
ALTER TABLE msales_mfeb20 ADD CONSTRAINT y2020m02
   CHECK ( logdate >= DATE '2020-02-01' AND logdate < DATE '2020-03-01' );

-- add data or other prep work
```

To add this existing table to a partition hierarchy, use `ALTER TABLE ... ATTACH PARTITION`: For example:

```
-- attach to the partition hierarchy, specifying the boundaries/constraints
ALTER TABLE msales ATTACH PARTITION msales_mfeb20
  FOR VALUES FROM ('2020-02-01') TO ('2020-03-01');
```

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The `ATTACH PARTITION` command requires taking a `SHARE UPDATE EXCLUSIVE` lock on the partitioned table.

Before running the `ATTACH PARTITION` command, consider creating a `CHECK` constraint on the table to be attached that matches the expected partition constraint, as illustrated above. If you do this, the system skips the scan which is otherwise required to validate the implicit partition constraint. Without the `CHECK` constraint, WarehousePG scans the table to validate the partition constraint while holding an `ACCESS EXCLUSIVE` lock on that partition. Be sure to drop the now-redundant `CHECK` constraint after the `ATTACH PARTITION` completes. If the table being attached is itself a partitioned table, then WarehousePG recursively locks and scans each of its sub-partitions until it encounters either a suitable `CHECK` constraint or reaches the leaf partitions.

Similarly, if the partitioned table has a `DEFAULT` partition, consider creating a `CHECK` constraint that excludes the to-be-attached partition's constraint. If you do not do this, WarehousePG scans the `DEFAULT` partition to verify that it contains no records which should be located in the partition being attached. WarehousePG performs this operation whiling holding an `ACCESS EXCLUSIVE` lock on the `DEFAULT` partition. If the `DEFAULT` partition is itself a partitioned table, then WarehousePG recursively checks each of its partitions in the same way as the table being attached, as mentioned above.

Indexing Partitioned Tables

Creating an index on the key column(s) of a partitioned table automatically creates a matching index on each partition, and any partitions that you create or attach later will also have such an index. An index or unique constraint declared on a partitioned table is "virtual" in the same way that the partitioned table is: the actual data is in child indexes on the individual partition tables.

Creating indexes on partitioned tables so that they are applied automatically to the entire hierarchy is very convenient; not only will the existing partitions be indexed, but any partitions that are created in the future will be indexed as well. To avoid long lock times, you can `CREATE INDEX ON ONLY` the partitioned table. Such an index is marked invalid, and WarehousePG does not apply the index automatically to the partitions. You can create the indexes on partitions individually, and then attach to the index on the parent using `ALTER INDEX .. ATTACH PARTITION`. After indexes for all partitions are attached to the parent index, the parent index is marked valid automatically. For example:

```
CREATE INDEX measurement_usls_idx ON ONLY measurement (unitsales);

CREATE INDEX measurement_usls_202102_idx
    ON measurement_y2021m02 (unitsales);
ALTER INDEX measurement_usls_idx
    ATTACH PARTITION measurement_usls_202102_idx;
...
```

You can use this technique with `UNIQUE` and `PRIMARY KEY` constraints too; the indexes are created implicitly when the constraint is created. Example:

```
ALTER TABLE ONLY measurement ADD UNIQUE (city_id, logdate);

ALTER TABLE measurement_y2021m02 ADD UNIQUE (city_id, logdate);
ALTER INDEX measurement_city_id_logdate_key
    ATTACH PARTITION measurement_y2021m02_city_id_logdate_key;
...
```

Renaming a Partition

You rename a partition in a partition hierarchy in the same way you rename a table, using the `ALTER TABLE ... RENAME TO` command.

```
ALTER TABLE msales_mfeb17 RENAME TO msales_month_feb17;
```

Adding a Default Partition

The `DEFAULT` keyword identifies a partition as the default partition. When it encounters data that falls outside of the boundaries of all partitions, Greeplum Database routes the data to the default partition. WarehousePG will reject incoming data if it does not match the constraint of any partition and there is no default partition defined, and returns an error. Identifying a default partition ensures that incoming data that does not match a partition is inserted into the partitioned table.

A partitioned table can only have one default partition. You can add a default partition to a partition hierarchy during or after table creation.

To identify a partition as a default partition when you create the table:

```
CREATE TABLE msales_other PARTITION OF msales DEFAULT;
```

To identify a table as a default partition after table creation:

```
-- previously created table that has the same schema as the root
CREATE TABLE msales_other (LIKE msales);
```

```
-- attach to the partition hierarchy
ALTER TABLE msales ATTACH PARTITION msales_other DEFAULT;
```

Dropping a Partition

The simplest option for removing old data is to drop the partition that is no longer necessary:

```
DROP TABLE measurement_y2020m02;
```

This operation can very quickly delete millions of records because it doesn't have to individually delete every record. Note, however, that the above command requires taking an `ACCESS EXCLUSIVE` lock on the parent table.

Another option is to remove the partition from the partitioned table but retain access to it as a table in its own right. See Detaching a Partition below.

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Detaching a Partition

You can detach a partition from your partition hierarchy using the `ALTER TABLE ... DETACH PARTITION` command. Detaching a partition removes it from the partition hierarchy, but *does not drop the table*. Detaching a partition that has sub-partitions automatically detaches those partitions as well.

For range partitions, it is common to detach the older partitions to roll old data out of the data warehouse. For example:

```
ALTER TABLE msales DETACH PARTITION msales_2021;
```

Detaching allows further operations to be performed on the data before it is dropped. For example, this may be an opportune time to back up the data using `COPY` or similar tools. You might also choose to aggregate data into smaller formats, perform other data manipulations, or run reports.

Truncating a Partition

Truncating a partition is the same as truncating any table. When you truncate a partition that is partitioned itself, WarehousePG automatically truncates the sub-partitions as well.

Truncate a partition:

```
TRUNCATE ONLY msales_other;
```

Truncate the whole partitioned table:

```
TRUNCATE msales;
```

Exchanging a Partition

Exchanging a partition swaps one table in place of an existing partition. To exchanging a partition, `DETACH` the original partition and then `ATTACH` the new partition. You can exchange partitions only at the lowest level of your partition hierarchy (only partitions that contain data can be exchanged).

You cannot exchange a partition with a replicated table. Exchanging a partition with a partitioned table or a non-leaf child partition of a partitioned table is also not supported.

> **Note** WarehousePG always validates the data against the partition constraint. You must ensure that the data in the table that you are attaching is valid against the constraints on the partition.

```
ALTER TABLE msales DETACH PARTITION msales_2021;
ALTER TABLE msales ATTACH PARTITION msales_2021_new FOR VALUES FROM (2021) TO (2022);
```

Best Practices

Choose the table partitioning strategy carefully, as the performance of query planning and execution can be negatively affected by poor design.

One of the most critical design decisions you must make is choosing the column or columns by which you partition your data. The best choice is often to partition by the column or set of columns which most commonly appear in `WHERE` clauses of queries being run on the partitioned table. WarehousePG can use `WHERE` clauses that are compatible with the partition bound constraints to prune unneeded partitions. However, you may be forced into making other decisions by requirements for the `PRIMARY KEY` or a `UNIQUE` constraint. Removal of unwanted data is also a factor to consider when you plann your partitioning strategy. An entire partition can be detached fairly quickly, so it may be beneficial to design the partition strategy in such a way that all data that you wnat to remove at once is located in a single partition.

Choosing the target number of partitions that the table should be divided into is also a critical decision. Not having enough partitions may mean that indexes remain too large and that data locality remains poor, which could result in low cache hit ratios. However, dividing the table into too many partitions can also cause issues. Too many partitions can result in longer query planning times and higher memory consumption during both query planning and execution, as further described below. When choosing how to partition your table, it's also important to consider what changes may occur in the future. For example, if you choose to have one partition per customer and you currently have a small number of large customers, consider the implications if in several years you instead find yourself with a large number of small customers. In this case, it may be better to choose to partition by `HASH` and choose a reasonable number of partitions rather than trying to partition by `LIST` and hoping that the number of customers does not increase beyond what it is practical to partition the data by.

Sub-partitioning can be useful to further divide partitions that are expected to become larger than other partitions. Another option is to use range partitioning with multiple columns in the partition key. Either of these can easily lead to excessive numbers of partitions, so restraint is advisable.

It is important to consider the overhead of partitioning during query planning and execution. The query planner and optimizer are generally able to handle partition hierarchies with up to a few thousand partitions fairly well, provided that typical queries allow the query planner to prune all but a small number of partitions. Planning times become longer and memory consumption becomes higher when more partitions remain after the planner performs partition pruning. This is particularly true for the `UPDATE` and `DELETE` commands. Another reason for concern about a large number of partitions is that the server's memory consumption may grow significantly over time, especially if many sessions touch large numbers of partitions. That's because each partition requires its metadata to be loaded into the local memory of each session that touches it.

If your workloads are performing data warehousing tasks, it can make sense to use a larger number of partitions than with an OLTP type workload. Generally, in data warehouses, query planning time is less of a concern as the majority of processing time is spent during query execution. With either of these two types of workload, it is important to make the right decisions early, as re-partitioning large quantities of data can be painfully slow. Simulations of the intended workload are often beneficial for optimizing the partitioning strategy. Never just assume that more partitions are better than fewer partitions, nor vice-versa.

Limitations

Take note of the following WarehousePG partitioned table limitations:

- A partitioned table can have a maximum of 32,767 partitions at each level.
- WarehousePG does not support partitioning replicated tables (tables created with the `DISTRIBUTED REPLICATED` distribution policy).
- The WarehousePG query optimizer (GPORCA) does not support uniform multi-level partitioned tables. If GPORCA is enabled (the default) and the partitioned table is multi-level, WarehousePG runs queries against the table with the Postgres-based planner.
- The WarehousePG `gpbackup` utility does not back up data from a leaf partition of a partitioned table when the leaf partition is an external or foreign table.
- To create a unique or primary key constraint on a partitioned table, the partition keys must not include any expressions or function calls and the constraint's columns must include all of the partition key columns. This limitation exists because the individual indexes making up the constraint can only directly enforce uniqueness within their own partitions; the partition structure itself must guarantee that there are not duplicates in different partitions.
- There is no way to create an exclusion constraint spanning the whole partitioned table. You can put such a constraint only on each leaf partition individually. This limitation stems from not being able to enforce cross-partition restrictions.
- Mixing temporary and permanent relations in the same partition hierarchy is not allowed. If the partitioned table is permanent, so must be its partitions and likewise if the partitioned table is temporary. When using temporary relations, all members of the partition hierarchy must be from the same session.

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Individual partitions are linked to their partitioned table using inheritance behind the scenes. However, it is not possible to use all of the generic features of inheritance with declaratively partitioned tables or their partitions, as discussed below. Notably, a partition cannot have any parents other than the partitioned table it is a partition of, nor can a table inherit from both a partitioned table and a regular table. Partitioned tables and their partitions never share an inheritance hierarchy with regular tables.

Since a partition hierarchy consisting of the partitioned table and its partitions is still an inheritance hierarchy, `tableoid` and all of the normal rules of inheritance apply as described in Inheritance in the PostgreSQL documentation, with a few exceptions:

- Partitions cannot have columns that are not present in the parent. It is not possible to specify columns when creating partitions with `CREATE TABLE`, nor is it possible to add columns to partitions after-the-fact using `ALTER TABLE`. Tables may be added as a partition with `ALTER TABLE ... ATTACH PARTITION` only if their columns exactly match the parent.
- Both `CHECK` and `NOT NULL` constraints of a partitioned table are always inherited by all of its partitions. WarehousePG does not permit `CHECK` constraints that are marked `NO INHERIT` to be created on partitioned tables. You cannot drop a `NOT NULL` constraint on a partition's column if the same constraint is present in the parent table.
- Using `ONLY` to add or drop a constraint on only the partitioned table is supported as long as there are no partitions. Once partitions exist, using `ONLY` will result in an error. Instead, constraints on the partitions themselves can be added and (if they are not present in the parent table) dropped.
- As a partitioned table does not have any data itself, attempts to use `TRUNCATE ONLY` on a partitioned table always return an error.

When a leaf partition is an external or foreign table, the following limitations hold:

- If the external or foreign table partition is not writable or the user does not have permission to write to the table, commands that attempt to modify data in the external or foreign partition (`INSERT`, `DELETE`, `UPDATE`, or `TRUNCATE`) return an error.

- A `COPY` command cannot copy data to a partitioned table that updates an external or foreign table partition.

- A `COPY` command that attempts to copy from an external or foreign table partition returns an error unless you specify the `IGNORE EXTERNAL PARTITIONS` clause. When you specify the clause, WarehousePG does not copy data from external or foreign table partitions.

  To use the `COPY` command against a partitioned table with a leaf partition that is an external or foreign table, use an SQL expression rather than the partitioned table name to copy the data. For example, if the table `my_sales` contains a leaf partition that is an external table, this command sends the data to `stdout`:

  ```
  COPY (SELECT * from my_sales ) TO stdout
  ```

- `VACUUM` commands skip external and foreign table partitions.

- If the external or foreign table partition is not writable or the user does not have permission to write to the table, WarehousePG returns an error on the following operations:

  - Adding or dropping a column.
  - Changing the data type of a column.

These (*classic syntax*) `ALTER TABLE ... ALTER PARTITION` operations are not supported when the partitioned table contains an external or foreign table partition:

- Setting a sub-partition template.
- Altering the partition properties.
- Creating a default partition.
- Setting a distribution policy.
- Setting or dropping a `NOT NULL` constraint of column.
- Adding or dropping constraints.
- Splitting an external partition.

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4.4.7.1 About Changes to Table Partitioning in WarehousePG 7

WarehousePG 7 retains most aspects of the partitioning syntax of prior versions of WarehousePG, now referred to as the *classic* partitioning syntax. Version 7 also introduces support for a *modern* syntax, derived from the PostgreSQL declarative partitioning syntax.

This topic describes the WarehousePG 7 partitioning syntax and behavior changes, and is geared toward existing users of WarehousePG 6.

(Refer to Partitioning Large Tables for information about using both syntaxes to create and manage partitioned tables.)

Parent topic: DDL: Defining Database Objects

What's New?

The following partitioning-related features are *new* in WarehousePG 7:

- Support for PostgreSQL declarative partitioning syntax, which introduces these new features *for the modern syntax only*:
    - Partitions are first-class tables.
    - The table name of a partition is just that, not an alias.
    - Support for the hash partitioning strategy.
    - Support for multi-column range partitioning.
    - Support for specifying an expression in the partition key.
    - A partitioned table may have zero partitions.
    - Support for a heterogeneous partition hierarchy that allows child partitions of different levels and allows for different partitioning strategies amongst the child partitions.
- Less restrictive locking in `ATTACH PARTITION`. You can now attach a partition to a partition hierarchy without disrupting many normal query executions on the partition.
- `GRANT ... ONLY` and `REVOKE ... ONLY` syntaxes that direct WarehousePG to apply the operation to the named table only (does not recurse the operation to child tables).
- `ALTER TABLE ONLY` syntax that directs WarehousePG to apply the operation to the named table only (does not recurse the operation to child tables).

What Hasn't Changed With Classic Syntax?

The following classic partitioning syntax and behaviors *have not* changed in WarehousePG 7:

- WarehousePG 7 supports the classic partitioning syntax of WarehousePG 6 except where called out in the What Has Changed? section.
- Support for range and list partition strategies.
- Support for sub-partition templates.
- A partitioned table must be defined with at least one partition.
- Only leaf partitions contain data.
- The name that you assign a partition table is an alias.
- By default, a `GRANT` or `REVOKE` operation on a parent partitioned table recurses to its child tables.
- By default, an `ALTER TABLE` operation on a parent partitioned table recurses to its child tables.

What Has Changed?

The following items describe the WarehousePG 7 *changes* to classic partitioning syntax and behaviors compared to WarehousePG 6:

- New internal data structures and catalogs are used to represent partitioned tables.

    > **Important** WarehousePG 7 represents and operates on partitioned tables using the new internal data structures and catalog, regardless of the partitioning syntax used to create the table. Operations that you invoke using the classic partitioning syntax are internally mapped to the new data structures, and any output generated by WarehousePG, such as DDL, is displayed in that format.

- These partitioning-related catalog tables, views, and functions are removed:
    - `pg_partition`
    - `pg_partition_rule`
    - `pg_partition_columns`
    - `pg_partition_encoding`
    - `pg_partition_rule`
    - `pg_partition_templates`
    - `pg_partitions`
    - `pg_stat_partition_operations`
    - `pg_partition_def()`

    The new pg_partitioned_table catalog table and `pg_partition_tree()`, `pg_partition_ancestors()`, and `pg_partition_root()` functions provide similar information. Refer to About Viewing Your Partition Design for more information on these new functions.

- The `FOR (RANK(<value>))` clause is no longer supported. When creating or altering a partitioned table, you must locate a partition by `VALUE`.

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- Partition boundaries are no longer represented as `CHECK` constraints, but rather internally-constructed partition constraints.
- The level of a partition in the partition hierarchy differs in WarehousePG 6 and WarehousePG 7. In WarehousePG 6, the level of the immediate child of a partitioned table is 0. In WarehousePG 7, the level of the partitioned table itself is 0, and the level of its immediate child is 1.
- The interpretation of `START` / `END` and `EXCLUSIVE` / `INCLUSIVE` clauses for range partition boundaries has changed:
  - When a clause is not specified, the start boundary is always inclusive and the end boundary exclusive (same behaviour as WarehousePG 6).
  - When `START EXCLUSIVE <n>` is specified, WarehousePG now implicitly converts this to a `START INCLUSIVE <n>+1`.
  - When an `END INCLUSIVE <n>` is specified, WarehousePG now implicitly converts this to an `END EXCLUSIVE <n>+1`.
  - Because of the implicit conversion mentioned in the previous points, `START EXCLUSIVE` and `END INCLUSIVE` boundaries are now permitted only for data types that have a suitable `+` operator like `integer` and `timestamp` (but not `float` or `text`).
- Partition-specific information displayed in `psql` `\d+` output has changed:
  - Partition boundaries are now tagged `Partition constraint`.
  - Instead of `Inherits`, the parent table is now identified with the tag `Partition of`
  - Range partition boundaries defined with `START` / `END` are displayed using the (modern syntax) `FOR VALUES [ FROM/TO | IN | WITH ]` keywords.
  - Example:

```
\d+ jan_sales
                                Table "public.jan_sales"
 Column |     Type      | Collation | Nullable | Default | Storage | Stats target | Description
|--------+---------------+-----------+----------+---------+---------+--------------+-------------
 id     | integer       |           |          |         | plain   |              |
 date   | date          |           |          |         | plain   |              |
 amt    | numeric(10,2) |           |          |         | main    |              |
Partition of: sales FOR VALUES FROM ('2023-01-01') TO ('2023-02-01')
Partition constraint: ((date IS NOT NULL) AND (date >= '2023-01-01'::date) AND (date < '2023-02-01'::date))
Distributed by: (id)
```

- The `EXCHANGE PARTITION` command has changed:
  - This command is now internally implemented with the `DETACH PARTITION` and `ATTACH PARTITION` commands introduced with the modern syntax.
  - The partition-to-exchange is no longer required to have the same owner as the parent table.
  - The partition-to-exchange is no longer required to have the same index as the parent table. The command will create one if it is missing.
  - The partition-to-exchange must have the same constraint as the parent table.
  - Previous versions renamed the tables and also renamed the index and constraints, in WarehousePG 7, this command only renames the table.
- Property inheritance changes:
  - A created/added partition inherits the properties of its parent.
  - The partitions created from a `SPLIT PARTITION` inherit the properties of the split child.
  - An attached partition maintains its original properties.

> **Note** The WarehousePG query optimizer (GPORCA) does not support multi-level partitioned tables.

Additional Considerations

Additional factors to consider:

- You must change any scripts that you wrote that depend on DDL or `psql \d` output.
- WarehousePG 7 dumps and restores the DDL of partitioned tables defined with classic syntax using the new catalog structures.

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4.4.7.2 Examples Using the Classic Partitioning Syntax

The classic partitioning syntax reflects the partitioning syntax of prior versions of WarehousePG. It is most appropriate for a homogenous partitioned table, where all partitions are at the same leaf level and have the same partition rule.

If you are already familiar with the *classic* partitioning syntax, refer to About Changes to Table Partitioning in WarehousePG 7 for information about syntax and behavior changes introduced in version 7.

Creating Partitioned Tables with the Classic Syntax

This section includes several examples that use the classic syntax for creating a partitioned table.

Creating a Date-Range Partitioned Table

A date-range partitioned table uses a single date type column as the partition key column.

With the classic syntax, you can instruct WarehousePG to automatically generate partitions by providing a `START` value, an `END` value, and an `EVERY` clause that defines the partition increment value. By default, `START` values are always inclusive and `END` values are always exclusive. For example, to create a daily-partitioned table named `sales:

```
CREATE TABLE sales (id int, date date, amt decimal(10,2))
DISTRIBUTED BY (id)
PARTITION BY RANGE (date)
( START (date '2022-01-01') INCLUSIVE
   END (date '2023-01-01') EXCLUSIVE
   EVERY (INTERVAL '1 day') );
```

You can also declare and name each partition individually. For example:

```
CREATE TABLE sales (id int, date date, amt decimal(10,2))
DISTRIBUTED BY (id)
PARTITION BY RANGE (date)
( PARTITION Jan22 START (date '2022-01-01') INCLUSIVE ,
  PARTITION Feb22 START (date '2022-02-01') INCLUSIVE ,
  PARTITION Mar22 START (date '2022-03-01') INCLUSIVE ,
  PARTITION Apr22 START (date '2022-04-01') INCLUSIVE ,
  PARTITION May22 START (date '2022-05-01') INCLUSIVE ,
  PARTITION Jun22 START (date '2022-06-01') INCLUSIVE ,
  PARTITION Jul22 START (date '2022-07-01') INCLUSIVE ,
  PARTITION Aug22 START (date '2022-08-01') INCLUSIVE ,
  PARTITION Sep22 START (date '2022-09-01') INCLUSIVE ,
  PARTITION Oct22 START (date '2022-10-01') INCLUSIVE ,
  PARTITION Nov22 START (date '2022-11-01') INCLUSIVE ,
  PARTITION Dec22 START (date '2022-12-01') INCLUSIVE
                  END (date '2023-01-01') EXCLUSIVE );
```

You need not declare an `END` value for each partition, only the last one. In this example, `Jan22` ends where `Feb22` starts.

Creating a Numeric-Range Partitioned Table

A numeric-range partitioned table uses a single numeric type column as the partition key column.

For example, create a table named `nrank` that is numeric-range partitioned on the `int` column `year`:

```
CREATE TABLE nrank (id int, rank int, year int, color char(1), count int)
DISTRIBUTED BY (id)
PARTITION BY RANGE (year)
( START (2012) END (2022) EVERY (1),
  DEFAULT PARTITION extra );
```

Creating a List Partitioned Table

A list partitioned table can use any data type column that allows equality comparisons as its partition key column. With the classic syntax, a list partition can have a multi-column (composite) partition key. For list partitions, you must declare a partition for every list value. For example:

```
CREATE TABLE rank (id int, rank int, year int, color char(1), count int )
DISTRIBUTED BY (id)
PARTITION BY LIST (color)
( PARTITION red VALUES ('r'),
  PARTITION blue VALUES ('b'),
  PARTITION green VALUES ('g'),
  DEFAULT PARTITION other );
```

> **Note** While the Postgres-based planner allows list partitions with multi-column (composite) partition keys, the WarehousePG query optimizer (GPORCA) does not support this.

Defining Multi-level Partitions

You can create a multi-level partition design with sub-partitions of partitions. Using a *sub-partition template* ensures that every partition has the same sub-partition design, including partitions that you add later. For example, the following SQL creates the two-level partition design shown in Example Multi-Level Partition Design:

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```
CREATE TABLE sales (trans_id int, date date, amount decimal(9,2), region text)
DISTRIBUTED BY (trans_id)
PARTITION BY RANGE (date)
SUBPARTITION BY LIST (region)
SUBPARTITION TEMPLATE
( SUBPARTITION usa VALUES ('usa'),
  SUBPARTITION asia VALUES ('asia'),
  SUBPARTITION europe VALUES ('europe'),
  DEFAULT SUBPARTITION other_regions)
  (START (date '2011-01-01') INCLUSIVE
   END (date '2012-01-01') EXCLUSIVE
   EVERY (INTERVAL '1 month'),
   DEFAULT PARTITION outlying_dates );
```

The following example shows a three-level partition design where the `sales` table is partitioned by `year`, then `month`, then `region`. The `SUBPARTITION TEMPLATE` clauses ensure that each yearly partition has the same sub-partition structure. The example declares a `DEFAULT` partition at each level of the hierarchy.

```
CREATE TABLE p3_sales (id int, year int, month int, day int,
region text)
DISTRIBUTED BY (id)
PARTITION BY RANGE (year)
    SUBPARTITION BY RANGE (month)
       SUBPARTITION TEMPLATE (
        START (1) END (13) EVERY (1),
        DEFAULT SUBPARTITION other_months )
           SUBPARTITION BY LIST (region)
             SUBPARTITION TEMPLATE (
               SUBPARTITION usa VALUES ('usa'),
               SUBPARTITION europe VALUES ('europe'),
               SUBPARTITION asia VALUES ('asia'),
               DEFAULT SUBPARTITION other_regions )
( START (2002) END (2012) EVERY (1),
  DEFAULT PARTITION outlying_years );
```

CAUTION: When you create multi-level partitions on ranges, it is easy to create a large number of sub-partitions, some containing little or no data. This can add many entries to the system tables, which increases the time and memory required to optimize and run queries. Increase the range interval or choose a different partitioning strategy to reduce the number of sub-partitions created.

Partitioning an Existing Table

With classic syntax, tables can be partitioned only at creation. If you have a table that you want to partition, you must create a partitioned table, load the data from the original table into the new table, drop the original table, and rename the partitioned table with the original table's name. You must also re-grant any table permissions. For example:

```
CREATE TABLE sales2 (LIKE sales)
PARTITION BY RANGE (date)
( START (date 2016-01-01') INCLUSIVE
   END (date '2017-01-01') EXCLUSIVE
   EVERY (INTERVAL '1 month') );
INSERT INTO sales2 SELECT * FROM sales;
DROP TABLE sales;
ALTER TABLE sales2 RENAME TO sales;
GRANT ALL PRIVILEGES ON sales TO admin;
GRANT SELECT ON sales TO guest;
```

> **Note** The `LIKE` clause does not copy over partition structures when creating a new table.

Partition Maintenance with the Classic Syntax

To maintain a partitioned table that you created with the classic syntax, use the `ALTER TABLE` command against the top-level root partitioned table. The most common scenario is to drop old partitions and add new ones to maintain a rolling window of data in a range partition design. You can convert (*exchange*) older partitions to the append-optimized compressed storage format to save space. If you have a default partition in your partition design, you add a partition by *splitting* the default partition.

- Adding a Partition
- Renaming a Partition
- Adding a Default Partition
- Dropping a Partition
- Truncating a Partition
- Exchanging a Partition
- Splitting a Partition
- Modifying a Sub-Partition Template
- Exchanging a Leaf Partition with an External Table

> **Important** When defining and altering partition designs, use the given partition name, not the table object name. The given partition name is the `relid` column returned by the `pg_partition_tree()` function. Although you can query and load any table (including partitioned tables) directly using SQL commands, you can only modify the structure of a partitioned table that you create with classic partitioning syntax using the `ALTER TABLE ... PARTITION` clauses.

Partitions are not required to have names. If a partition does not have a name, use the following expression to identify a partition: `PARTITION FOR (value)`.

For a multi-level partitioned table, you identify a specific partition to change with `ALTER PARTITION` clauses. For each partition level in the table hierarchy that is above the target partition, specify the partition that is related to the target partition in an `ALTER PARTITION` clause. For example, if you have a partitioned table that consists of three levels, year, quarter, and region, this `ALTER TABLE` command exchanges a leaf partition `region` with the table `region_new`.

```
ALTER TABLE sales ALTER PARTITION year_1 ALTER PARTITION quarter_4 EXCHANGE PARTITION region WITH TABLE region_new ;
```

The two `ALTER PARTITION` clauses identify which `region` partition to exchange. Both clauses are required to identify the specific leaf partition to exchange.

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Adding a Partition

You can add a partition to a partition design with the `ALTER TABLE` command. If the original partition design included sub-partitions defined by a *sub-partition template*, the newly added partition is sub-partitioned according to that template. For example:

```
ALTER TABLE sales ADD PARTITION
            START (date '2017-02-01') INCLUSIVE
            END (date '2017-03-01') EXCLUSIVE;
```

If you did not use a sub-partition template when you created the table, you define sub-partitions when adding a partition:

```
ALTER TABLE sales ADD PARTITION
            START (date '2017-02-01') INCLUSIVE
            END (date '2017-03-01') EXCLUSIVE
      ( SUBPARTITION usa VALUES ('usa'),
        SUBPARTITION asia VALUES ('asia'),
        SUBPARTITION europe VALUES ('europe') );
```

When you add a sub-partition to an existing partition, you can specify the partition to alter. For example:

```
ALTER TABLE sales ALTER PARTITION FOR ('2017-02-07'::date)
      ADD PARTITION africa VALUES ('africa');
```

> **Note** You cannot add a partition to a partition design that has a default partition. You must split the default partition to add a partition. See Splitting a Partition.

Renaming a Partition

Sub-partition tables created with the classic syntax use the following naming convention. Partitioned subtable names are subject to uniqueness requirements and length limitations.

```
<parentname>_<level>_prt_<partition_name>
```

For example:

```
sales_1_prt_jan16
```

For auto-generated range partitions, where a number is assigned when no name is given:

```
sales_1_prt_1
```

To rename a partitioned child table, rename the top-level parent table. The `<parentname>` changes in the table names of all associated child tables. For example, the following command:

```
ALTER TABLE sales RENAME TO globalsales;
```

Changes the associated table names:

```
globalsales_1_prt_1
```

You can change the name of a partition to make it easier to identify. For example:

```
ALTER TABLE sales RENAME PARTITION FOR ('2016-01-01') TO jan16;
```

Changes the associated table name as follows:

```
sales_1_prt_jan16
```

When altering partitioned tables with the `ALTER TABLE` command, always refer to the tables by their partition name (`jan16`) and not their full table name (`sales_1_prt_jan16`).

> **Note** The table name cannot be a partition name in an `ALTER TABLE` statement. For example, `ALTER TABLE sales...` is correct, `ALTER TABLE sales_1_part_jan16...` is not allowed.

Adding a Default Partition

You can add a default partition to a partition design with the `ALTER TABLE` command.

```
ALTER TABLE sales ADD DEFAULT PARTITION other;
```

If your partition design is multi-level, each level in the hierarchy must have a default partition. For example:

```
ALTER TABLE sales ALTER PARTITION FOR ('2017-03-01'::date) ADD DEFAULT PARTITION other;

ALTER TABLE sales ALTER PARTITION FOR ('2017-05-01'::date) ADD DEFAULT PARTITION other;

ALTER TABLE sales ALTER PARTITION FOR (2017-07-01::date) ADD DEFAULT PARTITION other;
```

If incoming data does not match a partition's constraint and there is no default partition, the data is rejected. Default partitions ensure that incoming data that does not match a partition is inserted into the default partition.

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Dropping a Partition

You can drop a partition from your partition design using the `ALTER TABLE` command. When you drop a partition that has sub-partitions, the sub-partitions (and all data in them) are automatically dropped as well. For range partitions, it is common to drop the older partitions from the range as old data is rolled out of the data warehouse. For example:

```
ALTER TABLE sales DROP PARTITION FOR ('2017-03-01'::date);
```

Truncating a Partition

You can truncate a partition using the `ALTER TABLE` command. When you truncate a partition that has sub-partitions, the sub-partitions are automatically truncated as well.

```
ALTER TABLE sales TRUNCATE PARTITION FOR ('2017-02-01'::date);
```

Exchanging a Partition

You can exchange a partition using the `ALTER TABLE` command. Exchanging a partition swaps one table in place of an existing partition. You can exchange partitions only at the lowest level of your partition hierarchy (only partitions that contain data can be exchanged).

Internally, WarehousePG converts an `ALTER TABLE ... EXCHANGE PARTITION` command into modern syntax `DETACH PARTITION` and `ATTACH PARTITION` commands (with some name swapping).

You cannot exchange a partition with a replicated table. Exchanging a partition with a partitioned table or a child partition of a partitioned table is not supported.

> **Note** WarehousePG always validates the data against the partition constraint. You must ensure that the data in the table that you are attaching is valid against the constraints on the partition.

Splitting a Partition

Splitting a partition divides a partition into two partitions. You can split a partition using the `ALTER TABLE` command. You can split partitions only at the lowest level of your partition hierarchy (partitions that contain data). For a multi-level partition, only range partitions can be split, not list partitions. The split value you specify goes into the *latter* partition.

For example, to split a monthly partition into two with the first partition containing dates January 1-15 and the second partition containing dates January 16-31:

```
ALTER TABLE sales SPLIT PARTITION FOR ('2017-01-01')
AT ('2017-01-16')
INTO (PARTITION jan171to15, PARTITION jan1716to31);
```

If your partition design has a default partition, you must split the default partition to add a partition.

When using the `INTO` clause, specify the current default partition as the second partition name. For example, to split a default range partition to add a new monthly partition for January 2017:

```
ALTER TABLE sales SPLIT DEFAULT PARTITION
START ('2017-01-01') INCLUSIVE
END ('2017-02-01') EXCLUSIVE
INTO (PARTITION jan17, default partition);
```

Modifying a Sub-Partition Template

Use `ALTER TABLE ... SET SUBPARTITION TEMPLATE` to modify the sub-partition template of a partitioned table. Partitions added after you set a new sub-partition template have the new partition design. Existing partitions are not modified.

The following example alters the sub-partition template of this partitioned table:

```
CREATE TABLE sales (trans_id int, date date, amount decimal(9,2), region text)
  DISTRIBUTED BY (trans_id)
  PARTITION BY RANGE (date)
  SUBPARTITION BY LIST (region)
  SUBPARTITION TEMPLATE
    ( SUBPARTITION usa VALUES ('usa'),
      SUBPARTITION asia VALUES ('asia'),
      SUBPARTITION europe VALUES ('europe'),
      DEFAULT SUBPARTITION other_regions )
  ( START (date '2014-01-01') INCLUSIVE
    END (date '2014-04-01') EXCLUSIVE
    EVERY (INTERVAL '1 month') );
```

This `ALTER TABLE` command, modifies the sub-partition template.

```
ALTER TABLE sales SET SUBPARTITION TEMPLATE
( SUBPARTITION usa VALUES ('usa'),
  SUBPARTITION asia VALUES ('asia'),
  SUBPARTITION europe VALUES ('europe'),
  SUBPARTITION africa VALUES ('africa'),
  DEFAULT SUBPARTITION regions );
```

When you add a date-range partition of the table sales, it includes the new regional list sub-partition for Africa. For example, the following command creates the sub-partitions `usa`, `asia`, `europe`, `africa`, and a default partition named `other`:

```
ALTER TABLE sales ADD PARTITION "4"
  START ('2014-04-01') INCLUSIVE
  END ('2014-05-01') EXCLUSIVE;
```

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To view the tables created for the partitioned table `sales`, you can use the command `\dt sales*` from the psql command line.

To remove a sub-partition template, use `SET SUBPARTITION TEMPLATE` with empty parentheses. For example, to clear the sales table sub-partition template:

```
ALTER TABLE sales SET SUBPARTITION TEMPLATE ();
```

Exchanging a Leaf Partition with an External Table

You can exchange a leaf partition of a partitioned table with a readable external table. The external table data can reside on a host file system, an NFS mount, or a Hadoop file system (HDFS).

For example, if you have a partitioned table that is created with monthly partitions and most of the queries against the table only access the newer data, you can copy the older, less accessed data to external tables and exchange older partitions with the external tables. For queries that only access the newer data, you could create queries that use partition elimination to prevent scanning the older, unneeded partitions.

Exchanging a leaf partition with an external table is not supported if the partitioned table contains a column with a check constraint or a `NOT NULL` constraint.

For information about exchanging and altering a leaf partition, see the ALTER TABLE command reference.

For information about limitations of partitioned tables that contain a external table partition, see Limitations of Partitioned Tables.

Example Exchanging a Partition with an External Table

This is a simple example that exchanges a leaf partition of this partitioned table for an external table. The partitioned table contains data for the years 2010 through 2013.

```
CREATE TABLE sales (id int, year int, qtr int, day int, region text)
  DISTRIBUTED BY (id)
  PARTITION BY RANGE (year)
  ( PARTITION yr START (2010) END (2014) EVERY (1) ) ;
```

There are four leaf partitions for the partitioned table. Each leaf partition contains the data for a single year. The leaf partition `sales_1_prt_yr_1` contains the data for the year 2010. These steps exchange the table `sales_1_prt_yr_1` with an external table the uses the `gpfdist` protocol:

1. Ensure that the external table protocol is enabled for the WarehousePG cluster.

   This example uses the `gpfdist` protocol. This command starts the `gpfdist` protocol.

   ```
   $ gpfdist
   ```

2. Create a writable external table.

   This `CREATE WRITABLE EXTERNAL TABLE` command creates a writable external table with the same columns as the partitioned table.

   ```
   CREATE WRITABLE EXTERNAL TABLE my_sales_ext ( LIKE sales_1_prt_yr_1 )
     LOCATION ( 'gpfdist://gpdb_test/sales_2010' )
     FORMAT 'csv'
     DISTRIBUTED BY (id) ;
   ```

3. Create a readable external table that reads the data from that destination of the writable external table created in the previous step.

   This `CREATE EXTERNAL TABLE` create a readable external that uses the same external data as the writable external data.

   ```
   CREATE EXTERNAL TABLE sales_2010_ext (LIKE sales_1_prt_yr_1)
     LOCATION ( 'gpfdist://gpdb_test/sales_2010' )
     FORMAT 'csv' ;
   ```

4. Copy the data from the leaf partition into the writable external table.

   This `INSERT` command copies the data from the leaf partition into the external table.

   ```
   INSERT INTO my_sales_ext SELECT * FROM sales_1_prt_yr_1;
   ```

5. Exchange the existing leaf partition with the external table.

   This `ALTER TABLE` command specifies the `EXCHANGE PARTITION` clause to switch the readable external table and the leaf partition.

   ```
   ALTER TABLE sales ALTER PARTITION yr_1
      EXCHANGE PARTITION yr_1
      WITH TABLE sales_2010_ext WITHOUT VALIDATION;
   ```

   The external table becomes the leaf partition with the table name `sales_1_prt_yr_1` and the old leaf partition becomes the table `sales_2010_ext`.

   > **Caution** In order to ensure queries against the partitioned table return the correct results, the external table data must be valid against the constraints on the leaf partition.

6. Drop the table that was rolled out of the partitioned table.

   ```
   DROP TABLE sales_2010_ext ;
   ```

You can rename the name of the leaf partition to indicate that `sales_1_prt_yr_1` is an external table.

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This example command changes the `partitionname` to `yr_1_ext` and the name of the leaf partition to `sales_1_prt_yr_1_ext`.

```
ALTER TABLE sales RENAME PARTITION yr_1 TO  yr_1_ext ;
```

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4.4.8 Creating and Using Sequences

A WarehousePG sequence object is a special single row table that functions as a number generator. You can use a sequence to generate unique integer identifiers for a row that you add to a table. Declaring a column of type `SERIAL` implicitly creates a sequence counter for use in that table column.

WarehousePG provides commands to create, alter, and drop a sequence. WarehousePG also provides built-in functions to return the next value in the sequence (`nextval()`) or to set the sequence to a specific start value (`setval()`).

> **Note** The PostgreSQL `currval()` and `lastval()` sequence functions are not supported in WarehousePG.

Attributes of a sequence object include the name of the sequence, its increment value, and the last, minimum, and maximum values of the sequence counter. Sequences also have a special boolean attribute named `is_called` that governs the auto-increment behavior of a `nextval()` operation on the sequence counter. When a sequence's `is_called` attribute is `true` , `nextval()` increments the sequence counter before returning the value. When the `is_called` attribute value of a sequence is `false` , `nextval()` does not increment the counter before returning the value.

Parent topic: DDL: Defining Database Objects

Creating a Sequence

The CREATE SEQUENCE command creates and initializes a sequence with the given sequence name and optional start value. The sequence name must be distinct from the name of any other sequence, table, index, or view in the same schema. For example:

```
CREATE SEQUENCE myserial START 101;
```

When you create a new sequence, WarehousePG sets the sequence `is_called` attribute to `false` . Invoking `nextval()` on a newly-created sequence does not increment the sequence counter, but returns the sequence start value and sets `is_called` to `true` .

Using a Sequence

After you create a sequence with the `CREATE SEQUENCE` command, you can examine the sequence and use the sequence built-in functions.

Examining Sequence Attributes

To examine the current attributes of a sequence, query the sequence directly. For example, to examine a sequence named `myserial` :

```
SELECT * FROM myserial;
```

Returning the Next Sequence Counter Value

You can invoke the `nextval()` built-in function to return and use the next value in a sequence. The following command inserts the next value of the sequence named `myserial` into the first column of a table named `vendors` :

```
INSERT INTO vendors VALUES (nextval('myserial'), 'acme');
```

`nextval()` uses the sequence's `is_called` attribute value to determine whether or not to increment the sequence counter before returning the value. `nextval()` advances the counter when `is_called` is `true` . `nextval()` sets the sequence `is_called` attribute to `true` before returning.

A `nextval()` operation is never rolled back. A fetched value is considered used, even if the transaction that performed the `nextval()` fails. This means that failed transactions can leave unused holes in the sequence of assigned values.

> **Note** You cannot use the `nextval()` function in `UPDATE` or `DELETE` statements if mirroring is enabled in WarehousePG.

Setting the Sequence Counter Value

You can use the WarehousePG `setval()` built-in function to set the counter value for a sequence. For example, the following command sets the counter value of the sequence named `myserial` to `201` :

```
SELECT setval('myserial', 201);
```

`setval()` has two function signatures: `setval(sequence, start_val)` and `setval(sequence, start_val, is_called)` . The default behaviour of `setval(sequence, start_val)` sets the sequence `is_called` attribute value to `true` .

If you do not want the sequence counter advanced on the next `nextval()` call, use the `setval(sequence, start_val, is_called)` function signature, passing a `false` argument:

```
SELECT setval('myserial', 201, false);
```

`setval()` operations are never rolled back.

nextval() and setval() Caution

To avoid blocking concurrent transactions that obtain numbers from the same sequence, the value obtained by `nextval()` is not reclaimed for re-use if the calling transaction later aborts. As such, transaction aborts or database crashes can result in gaps in the sequence of assigned values. This situation can occur without a transaction abort, also. For example, an `INSERT` with an `ON CONFLICT` clause will compute the to-be-inserted tuple, including invoking any required `nextval()` calls, before detecting any conflict that would cause it to follow the `ON CONFLICT` rule instead. Consequently, you cannot use WarehousePG sequence objects to obtain "gapless" sequences.

Similarly, sequence state changes made by `setval()` are immediately visible to other transactions, and are not undone if the calling transaction rolls back.

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If the database cluster crashes before committing a transaction containing a `nextval()` or `setval()` call, the sequence state change may not have been propogated to persistent storage, so that it is uncertain whether the sequence has its original or updated state after the cluster restarts. This is harmless for usage of the sequence within the database, since other effects of uncommitted transactions are visible either. However, if you wish to use a sequence value for persistent outside-the-database purposes, ensure that the `nextval()` call has been committed before doing so.

Altering a Sequence

The ALTER SEQUENCE command changes the attributes of an existing sequence. You can alter the sequence start, minimum, maximum, and increment values. You can also restart the sequence at the start value or at a specified value.

Any parameters not set in the `ALTER SEQUENCE` command retain their prior settings.

`ALTER SEQUENCE sequence START WITH start_value` sets the sequence's `start_value` attribute to the new starting value. It has no effect on the `last_value` attribute or the value returned by the `nextval(sequence)` function.

`ALTER SEQUENCE sequence RESTART` resets the sequence's `last_value` attribute to the current value of the `start_value` attribute and the `is_called` attribute to `false`. The next call to the `nextval(sequence)` function returns `start_value`.

`ALTER SEQUENCE sequence RESTART WITH restart_value` sets the sequence's `last_value` attribute to the new value and the `is_called` attribute to `false`. The next call to the `nextval(sequence)` returns `restart_value`. This is the equivalent of calling `setval(sequence, restart_value, false)`.

The following command restarts the sequence named `myserial` at value `105`:

```
ALTER SEQUENCE myserial RESTART WITH 105;
```

Dropping a Sequence

The DROP SEQUENCE command removes a sequence. For example, the following command removes the sequence named `myserial`:

```
DROP SEQUENCE myserial;
```

Specifying a Sequence as the Default Value for a Column

You can reference a sequence directly in the CREATE TABLE command in addition to using the `SERIAL` or `BIGSERIAL` types. For example:

```
CREATE TABLE tablename ( id INT4 DEFAULT nextval('myserial'), name text );
```

You can also alter a table column to set its default value to a sequence counter:

```
ALTER TABLE tablename ALTER COLUMN id SET DEFAULT nextval('myserial');
```

Sequence Wraparound

By default, a sequence does not wrap around. That is, when a sequence reaches the max value (`+32767` for `SMALLSERIAL`, `+2147483647` for `SERIAL`, `+9223372036854775807` for `BIGSERIAL`), every subsequent `nextval()` call produces an error. You can alter a sequence to make it cycle around and start at `1` again:

```
ALTER SEQUENCE myserial CYCLE;
```

You can also specify the wraparound behaviour when you create the sequence:

```
CREATE SEQUENCE myserial CYCLE;
```

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4.4.9 Using Indexes in WarehousePG

In most traditional databases, indexes can greatly improve data access times. However, in a distributed database such as WarehousePG, indexes should be used more sparingly. WarehousePG performs very fast sequential scans; indexes use a random seek pattern to locate records on disk. WarehousePG data is distributed across the segments, so each segment scans a smaller portion of the overall data to get the result. With table partitioning, the total data to scan may be even smaller. Because business intelligence (BI) query workloads generally return very large data sets, using indexes is not efficient.

First try your query workload without adding indexes. Indexes are more likely to improve performance for OLTP workloads, where the query is returning a single record or a small subset of data. Indexes can also improve performance on compressed append-optimized tables for queries that return a targeted set of rows, as the optimizer can use an index access method rather than a full table scan when appropriate. For compressed data, an index access method means only the necessary rows are uncompressed.

WarehousePG automatically creates `PRIMARY KEY` constraints for tables with primary keys. To create an index on a partitioned table, create an index on the partitioned table that you created. The index is propagated to all the child tables created by WarehousePG. Creating an index on a table that is created by WarehousePG for use by a partitioned table is not supported.

Note that a `UNIQUE CONSTRAINT` (such as a `PRIMARY KEY CONSTRAINT`) implicitly creates a `UNIQUE INDEX` that must include all the columns of the distribution key and any partitioning key. The `UNIQUE CONSTRAINT` is enforced across the entire table, including all table partitions (if any).

Indexes add some database overhead — they use storage space and must be maintained when the table is updated. Ensure that the query workload uses the indexes that you create, and check that the indexes you add improve query performance (as compared to a sequential scan of the table). To determine whether indexes are being used, examine the query `EXPLAIN` plans. See Query Profiling.

Consider the following points when you create indexes.

- **Your Query Workload.** Indexes improve performance for workloads where queries return a single record or a very small data set, such as OLTP workloads.
- Compressed Tables. Indexes can improve performance on compressed append-optimized tables for queries that return a targeted set of rows. For compressed data, an index access method means only the necessary rows are uncompressed.
- **Avoid indexes on frequently updated columns.** Creating an index on a column that is frequently updated increases the number of writes required when the column is updated.
- **Create selective B-tree indexes.** Index selectivity is a ratio of the number of distinct values a column has divided by the number of rows in a table. For example, if a table has 1000 rows and a column has 800 distinct values, the selectivity of the index is 0.8, which is considered good. Unique indexes always have a selectivity ratio of 1.0, which is the best possible. WarehousePG allows unique indexes only on distribution key columns.
- **Use Bitmap indexes for low selectivity columns.** The WarehousePG Bitmap index type is not available in regular PostgreSQL. See About Bitmap Indexes.
- **Index columns used in joins.** An index on a column used for frequent joins (such as a foreign key column) can improve join performance by enabling more join methods for the query optimizer to use.
- **Index columns frequently used in predicates.** Columns that are frequently referenced in `WHERE` clauses are good candidates for indexes.
- **Avoid overlapping indexes.** Indexes that have the same leading column are redundant.
- **Drop indexes for bulk loads.** For mass loads of data into a table, consider dropping the indexes and re-creating them after the load completes. This is often faster than updating the indexes.
- **Consider a clustered index.** Clustering an index means that the records are physically ordered on disk according to the index. If the records you need are distributed randomly on disk, the database has to seek across the disk to fetch the records requested. If the records are stored close together, the fetching operation is more efficient. For example, a clustered index on a date column where the data is ordered sequentially by date. A query against a specific date range results in an ordered fetch from the disk, which leverages fast sequential access.

Parent topic: DDL: Defining Database Objects

To cluster an index in WarehousePG

Using the `CLUSTER` command to physically reorder a table based on an index can take a long time with very large tables. To achieve the same results much faster, you can manually reorder the data on disk by creating an intermediate table and loading the data in the desired order. For example:

```
CREATE TABLE new_table (LIKE old_table)
       AS SELECT * FROM old_table ORDER BY myixcolumn;
DROP old_table;
ALTER TABLE new_table RENAME TO old_table;
CREATE INDEX myixcolumn_ix ON old_table;
VACUUM ANALYZE old_table;
```

Index Types

WarehousePG supports the Postgres index types B-tree, hash, GiST, SP-GiST, GIN, and BRIN. Each index type uses a different algorithm that is best suited to different types of queries. B-tree indexes fit the most common situations and are the default index type. See Index Types in the PostgreSQL documentation for a description of these types.

> **Note** WarehousePG allows unique indexes only if the columns of the index key are the same as (or a superset of) the WarehousePG distribution key. On a partitioned table, a unique index cannot be enforced across all child tables; a unique index is supported only within a child partition.

About Bitmap Indexes

WarehousePG provides the Bitmap index type. Bitmap indexes are best suited to data warehousing applications and decision support systems with large amounts of data, many ad hoc queries, and few data modification (DML) transactions.

An index provides pointers to the rows in a table that contain a given key value. A regular index stores a list of tuple IDs for each key corresponding to the rows with that key value. Bitmap indexes store a bitmap for each key value. Regular indexes can be several times larger than the data in the table, but bitmap indexes provide the same functionality as a regular index and use a fraction of the size of the indexed data.

Each bit in the bitmap corresponds to a possible tuple ID. If the bit is set, the row with the corresponding tuple ID contains the key value. A mapping function converts the bit position to a tuple ID. Bitmaps are compressed for storage. If the number of distinct key values is small, bitmap indexes are much smaller, compress better, and save considerable space compared with a regular index. The size of a bitmap index is proportional to the number of rows in the table times the number of distinct values in the indexed column.

Bitmap indexes are most effective for queries that contain multiple conditions in the `WHERE` clause. Rows that satisfy some, but not all, conditions are filtered out before the table is accessed. This improves response time, often dramatically.

When to Use Bitmap Indexes

Bitmap indexes are best suited to data warehousing applications where users query the data rather than update it. Bitmap indexes perform best for columns that have between 100 and 100,000 distinct values and when the indexed column is often queried in conjunction with other indexed columns. Columns with fewer than 100 distinct values, such as a gender column with two distinct values (male and female), usually do not benefit much from any type of index. On a column with more than 100,000 distinct values, the performance and space efficiency of a bitmap index decline.

Bitmap indexes can improve query performance for ad hoc queries. `AND` and `OR` conditions in the `WHERE` clause of a query can be resolved quickly by performing the corresponding Boolean operations directly on the bitmaps before converting the resulting bitmap to tuple ids. If the resulting number of rows is small, the query can be answered quickly without resorting to a full table scan.

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When Not to Use Bitmap Indexes

Do not use bitmap indexes for unique columns or columns with high cardinality data, such as customer names or phone numbers. The performance gains and disk space advantages of bitmap indexes start to diminish on columns with 100,000 or more unique values, regardless of the number of rows in the table.

Bitmap indexes are not suitable for OLTP applications with large numbers of concurrent transactions modifying the data.

Use bitmap indexes sparingly. Test and compare query performance with and without an index. Add an index only if query performance improves with indexed columns.

Creating an Index

The `CREATE INDEX` command defines an index on a table. A B-tree index is the default index type. For example, to create a B-tree index on the column *gender* in the table *employee*:

```
CREATE INDEX gender_idx ON employee (gender);
```

To create a bitmap index on the column *title* in the table *films*:

```
CREATE INDEX title_bmp_idx ON films USING bitmap (title);
```

Indexes on Expressions

An index column need not be just a column of the underlying table, but can be a function or scalar expression computed from one or more columns of the table. This feature is useful to obtain fast access to tables based on the results of computations.

Index expressions are relatively expensive to maintain, because the derived expressions must be computed for each row upon insertion and whenever it is updated. However, the index expressions are not recomputed during an indexed search, since they are already stored in the index. In both of the following examples, the system sees the query as just `WHERE indexedcolumn = 'constant'` and so the speed of the search is equivalent to any other simple index query. Thus, indexes on expressions are useful when retrieval speed is more important than insertion and update speed.

The first example is a common way to do case-insensitive comparisons with the `lower` function:

```
SELECT * FROM test1 WHERE lower(col1) = 'value';
```

This query can use an index if one has been defined on the result of the `lower(col1)` function:

```
CREATE INDEX test1_lower_col1_idx ON test1 (lower(col1));
```

This example assumes the following type of query is performed often.

```
SELECT * FROM people WHERE (first_name || ' ' || last_name) = 'John Smith';
```

The query might benefit from the following index.

```
CREATE INDEX people_names ON people ((first_name || ' ' || last_name));
```

The syntax of the `CREATE INDEX` command normally requires writing parentheses around index expressions, as shown in the second example. The parentheses can be omitted when the expression is just a function call, as in the first example.

Examining Index Usage

WarehousePG indexes do not require maintenance and tuning. You can check which indexes are used by the real-life query workload. Use the `EXPLAIN` command to examine index usage for a query.

The query plan shows the steps or *plan nodes* that the database will take to answer a query and time estimates for each plan node. To examine the use of indexes, look for the following query plan node types in your `EXPLAIN` output:

- **Index Scan** - A scan of an index.
- **Bitmap Heap Scan** - Retrieves all
- from the bitmap generated by BitmapAnd, BitmapOr, or BitmapIndexScan and accesses the heap to retrieve the relevant rows.
- **Bitmap Index Scan** - Compute a bitmap by OR-ing all bitmaps that satisfy the query predicates from the underlying index.
- **BitmapAnd** or **BitmapOr** - Takes the bitmaps generated from multiple BitmapIndexScan nodes, ANDs or ORs them together, and generates a new bitmap as its output.

You have to experiment to determine the indexes to create. Consider the following points.

- Run `ANALYZE` after you create or update an index. `ANALYZE` collects table statistics. The query optimizer uses table statistics to estimate the number of rows returned by a query and to assign realistic costs to each possible query plan.
- Use real data for experimentation. Using test data for setting up indexes tells you what indexes you need for the test data, but that is all.
- Do not use very small test data sets as the results can be unrealistic or skewed.
- Be careful when developing test data. Values that are similar, completely random, or inserted in sorted order will skew the statistics away from the distribution that real data would have.
- You can force the use of indexes for testing purposes by using run-time parameters to turn off specific plan types. For example, turn off sequential scans (`enable_seqscan`) and nested-loop joins (`enable_nestloop`), the most basic plans, to force the system to use a different plan. Time your query with and without indexes and use the `EXPLAIN ANALYZE` command to compare the results.

Managing Indexes

Use the `REINDEX` command to rebuild a poorly-performing index. `REINDEX` rebuilds an index using the data stored in the index's table, replacing the old copy of the index.

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To rebuild all indexes on a table

```
REINDEX my_table;
```

```
REINDEX my_index;
```

Dropping an Index

The `DROP INDEX` command removes an index. For example:

```
DROP INDEX title_idx;
```

When loading data, it can be faster to drop all indexes, load, then recreate the indexes.

About Indexes on Expressions

An index column need not be just a column of the underlying table, but can be a function or scalar expression computed from one or more columns of the table. This is useful to obtain fast access to a table based on the results of computations.

For example, a common way to do case-insensitive comparisons is to use the `lower()` function:

```
SELECT * FROM test1 WHERE lower(col1) = 'value';
```

This query can use an index if one has been defined on the result of the `lower(col1)` function:

```
CREATE INDEX test1_lower_col1_idx ON test1 (lower(col1));
```

If you declare this index `UNIQUE`, it prevents creation of rows whose `col1` values differ only in case, as well as rows whose `col1` values are actually identical. So, you can use indexes on expressions to enforce constraints that are not definable as simple unique constraints.

As another example, if you often invoke queries like:

```
SELECT * FROM people WHERE (first_name || ' ' || last_name) = 'John Smith';
```

then it might be worth creating an index like this:

```
CREATE INDEX people_names ON people ((first_name || ' ' || last_name));
```

The syntax of the `CREATE INDEX` command normally requires writing parentheses around index expressions, as shown in the second example. You can omit the parentheses when the expression is just a function call, as in the first example.

Index expressions are relatively expensive to maintain, because WarehousePG must compute the derived expression(s) for each row insertion and non-HOT update. However, WarehousePG does not recompute the index expressions during an indexed search, since they are already stored in the index. In both examples above, WarehousePG views the query as just `WHERE indexedcolumn = 'constant'` and so the speed of the search is equivalent to any other simple index query. Indexes on expressions are useful when retrieval speed is more important than insertion and update speed.

About Partial Indexes

A *partial index* is an index built over a subset of a table; the subset is defined by a conditional expression (called the predicate of the partial index). The index contains entries only for those table rows that satisfy the predicate. There are several situations in which a partial index is particularly useful.

One common reason for using a partial index is to avoid indexing common values. Since a query searching for a common value (one that accounts for more than a few percent of all the table rows) will not use the index anyway, there is no point in keeping those rows in the index at all. This reduces the size of the index, which will speed up those queries that do use the index. It will also speed up many table update operations because the index does not need to be updated in all cases.

Example: Setting up a Partial Index to Exclude Common Values

Suppose you are storing web server access logs in a database. Most accesses originate from the IP address range of your organization but some are from elsewhere (say, employees on dial-up connections). If your searches by IP are primarily for outside accesses, you probably do not need to index the IP range that corresponds to your organization's subnet.

Assume a table defined as such:

```
CREATE TABLE access_log (
    url varchar,
    client_ip inet,
    ...
);
```

To create a partial index that suits the example scenario, use the following command:

```
CREATE INDEX access_log_client_ip_ix ON access_log (client_ip)
WHERE NOT (client_ip > inet '192.168.100.0' AND
           client_ip < inet '192.168.100.255');
```

A typical query that can use this index follows:

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```
SELECT *
FROM access_log
WHERE url = '/index.html' AND client_ip = inet '212.78.10.32';
```

Here the query's IP address is covered by the partial index. The following query cannot use the partial index, as it uses an IP address that is excluded from the index:

```
SELECT *
FROM access_log
WHERE url = '/index.html' AND client_ip = inet '192.168.100.23';
```

Observe that this kind of partial index requires that the common values be predetermined, so such partial indexes are best used for data distributions that do not change. Such indexes can be recreated occasionally to adjust for new data distributions, adding to the maintenance effort.

Example: Setting up a Partial Index to Exclude Uninteresting Values

Another use for a partial index is to exclude values from the index that the typical query workload is not interested in. This results in the same advantages as listed above, but it prevents the "uninteresting" values from being accessed via that index, even if an index scan might be profitable in that case. Setting up partial indexes for this kind of scenario requires a lot of care and experimentation.

If you have a table that contains both billed and unbilled orders, where the unbilled orders take up a small fraction of the total table and yet those are the most-accessed rows, you can improve performance by creating an index on just the unbilled rows. The following command creates the index:

```
CREATE INDEX orders_unbilled_index ON orders (order_nr)
    WHERE billed is not true;
```

A query to use this index follows:

```
SELECT * FROM orders WHERE billed is not true AND order_nr < 10000;
```

However, you can also use the index in a query that does not involve `order_nr` at all, for example:

```
SELECT * FROM orders WHERE billed is not true AND amount > 5000.00;
```

This is not as efficient as a partial index on the `amount` column, since WarehousePG must scan the entire index. Yet, if there are relatively few unbilled orders, using this partial index just to find the unbilled orders could be a win.

Note that the following query cannot use this index:

```
SELECT * FROM orders WHERE order_nr = 3501;
```

The order `3501` might be among the billed or unbilled orders.

This example also illustrates that the indexed column and the column used in the predicate do not need to match. WarehousePG supports partial indexes with arbitrary predicates, so long as only columns of the table being indexed are involved. Keep in mind that the predicate must match the conditions used in the queries that are supposed to benefit from the index. To be precise, you can use a partial index in a query only if WarehousePG can recognize that the `WHERE` condition of the query mathematically implies the predicate of the index. WarehousePG cannot recognize mathematically equivalent expressions that are written in different forms. WarehousePG can recognize simple inequality implications, for example "x < 1" implies "x < 2"; otherwise the predicate condition must exactly match part of the query's `WHERE` condition or the index will not be recognized as usable. Matching takes place at query planning time, not at run time. As a result, parameterized query clauses do not work with a partial index. For example a prepared query with a parameter might specify "x < ?" which will never imply "x < 2" for all possible values of the parameter.

Example: Setting up a Partial Unique Index

A third possible use for partial indexes does not require the index to be used in queries at all. The idea here is to create a unique index over a subset of a table. This enforces uniqueness among the rows that satisfy the index predicate, without constraining those that do not.

Suppose that you have a table describing test outcomes. You want to ensure that there is only one "successful" entry for a given subject and target combination, but there might be any number of "unsuccessful" entries. Here is one way to satisfy those conditions:

```
CREATE TABLE tests (
    subject text,
    target text,
    success boolean,
    ...
);

CREATE UNIQUE INDEX tests_success_constraint ON tests (subject, target)
    WHERE success;
```

This is a particularly efficient approach when there are few successful tests and many unsuccessful ones. It is also possible to allow only one null in a column by creating a unique partial index with an `IS NULL` restriction.

Finally, a partial index can also be used to override WarehousePG's query plan choices. Also, data sets with peculiar distributions might cause the system to use an index when it really should not. In that case the index can be set up so that it is not available for the offending query. Normally, WarehousePG makes reasonable choices about index usage (it avoids them when retrieving common values, so the earlier example really only saves index size, it is not required to avoid index usage), and grossly incorrect plan choices are cause for a bug report.

Example: Do Not Use Partial Indexes as a Substitute for Partitioning

Keep in mind that setting up a partial index indicates that you know at least as much as the query planner knows, in particular you know when an index might be profitable. Forming this knowledge requires experience and understanding of how indexes in WarehousePG work. In most cases, the advantage of a partial index over a regular index will be minimal. There are cases where they are quite counterproductive.

Suppose you create a large set of non-overlapping partial indexes, for example:

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```
CREATE INDEX mytable_cat_1 ON mytable (data) WHERE category = 1;
CREATE INDEX mytable_cat_2 ON mytable (data) WHERE category = 2;
CREATE INDEX mytable_cat_3 ON mytable (data) WHERE category = 3;
...
CREATE INDEX mytable_cat_N ON mytable (data) WHERE category = N;
```

This is a bad idea! Almost certainly, you are better off with a single non-partial index, declared like:

```
CREATE INDEX mytable_cat_data ON mytable (category, data);
```

While a search in this larger index might have to descend through a couple more tree levels than a search in a smaller index, that's almost certainly going to be cheaper than the planner effort needed to select the appropriate one of the partial indexes. The core of the problem is that WarehousePG does not understand the relationship among the partial indexes, and tests each one to see if it is applicable to the current query.

If your table is large enough that a single index really is a bad idea, you should look into using partitioning instead. With that mechanism, WarehousePG does understand that the tables and indexes are non-overlapping, so far better performance is possible.

Understanding Index-Only Scans and Covering Indexes

> **Note** WarehousePG selects index-only and covering index scan options for a query plan only for new tables that you create in WarehousePG 7. WarehousePG does not select these plan types for tables that you have upgraded from WarehousePG 6.

All indexes in WarehousePG are secondary indexes, meaning that each index is stored separately from the table's main data area (which is called the table's heap). In an ordinary index scan, each row retrieval requires fetching data from both the index and the heap. While the index entries that match a given indexable `WHERE` condition are often close together in the index, the table rows they reference might reside anywhere in the heap. The heap-access portion of an index scan can involve a lot of random access into the heap, which can be slow, particularly on traditional rotating media. Bitmap scans try to alleviate this cost by doing the heap accesses in sorted order, but that only goes so far.

WarehousePG supports index-only scans to address the performance issue. Index-only scans can answer queries from an index alone without any heap access. WarehousePG returns values directly out of each index entry instead of consulting the associated heap entry. There are two fundamental restrictions on when WarehousePG can use this method:

1. The index type must support index-only scans. B-tree indexes always do. GiST and SP-GiST indexes support index-only scans for some operator classes but not others. Other index types have no support. The underlying requirement is that the index must physically store, or else be able to reconstruct, the original data value for each index entry. As a counterexample, GIN indexes cannot support index-only scans because each index entry typically holds only part of the original data value.

2. The query must reference only columns stored in the index. For example, given an index on columns `x` and `y` of a table that also has a column `z`, these queries could use index-only scans:

   ```
   SELECT x, y FROM tab WHERE x = 'key';
   SELECT x FROM tab WHERE x = 'key' AND y < 42;
   ```

   but these queries could not:

   ```
   SELECT x, z FROM tab WHERE x = 'key';
   SELECT x FROM tab WHERE x = 'key' AND z < 42;
   ```

   (Expression indexes and partial indexes complicate this rule, as discussed below.)

If these two fundamental requirements are met, then all the data values required by the query are available from the index, so an index-only scan is physically possible. But there is an additional requirement for any table scan in WarehousePG: it must verify that each retrieved row be "visible" to the query's MVCC snapshot. Because visibility information is not stored in index entries, only in heap entries, it might seem that every row retrieval would require a heap access anyway. And this is indeed the case, if the table row has been modified recently. However, for seldom-changing data there is a way around this problem. WarehousePG tracks, for each page in a table's heap, whether all rows stored in that page are old enough to be visible to all current and future transactions. This information is stored in a bit in the table's visibility map. An index-only scan, after finding a candidate index entry, checks the visibility map bit for the corresponding heap page. If it is set, the row is known visible and so WarehousePG can return the data with no further work. If it is not set, WarehousePG must visit the heap entry to find out whether it is visible, so no performance advantage is gained over a standard index scan. Even in the successful case, this approach trades visibility map accesses for heap accesses; but since the visibility map is four orders of magnitude smaller than the heap it describes, far less physical I/O is required to access it. In most situations the visibility map remains cached in memory all the time.

To summarize, while an index-only scan is possible given the two fundamental requirements, it will be a win only if a significant fraction of the table's heap pages have their all-visible map bits set. Because tables in which a large fraction of the rows are unchanging are common enough, this type of scan is very useful in practice.

To make effective use of the index-only scan feature, you may choose to create a covering index, which is an index specifically designed to include the columns required by a particular type of query that you run frequently. Since queries typically need to retrieve more columns than just the ones they search on, WarehousePG allows you to create an index in which some columns are just "payload" and are not part of the search key. You signal this by adding an `INCLUDE` clause that lists the extra columns. For example, if you commonly run queries like:

```
SELECT y FROM tab WHERE x = 'key';
```

the traditional approach to speeding up such queries would be to create an index on `x` only. However, an index defined as:

```
CREATE INDEX tab_x_y ON tab(x) INCLUDE (y);
```

could handle these queries as index-only scans, because `y` can be obtained from the index without visiting the heap.

Because column `y` is not part of the index's search key, it does not have to be of a data type that the index can handle; it is merely stored in the index and is not interpreted by the index machinery. Also, if the index is a unique index, that is:

```
CREATE UNIQUE INDEX tab_x_y ON tab(x) INCLUDE (y);
```

the uniqueness condition applies to just column `x`, not to the combination of `x` and `y`. (An `INCLUDE` clause can also be written in `UNIQUE` and `PRIMARY KEY` constraints, providing alternative syntax for setting up an index like this.)

Be conservative about adding non-key payload columns to an index, especially wide columns. If an index tuple exceeds the maximum size allowed for the index type, data insertion fails. Because non-key columns duplicate data from the index's table and bloat the size of the index, they can potentially slow searches. And remember that there is little point in including payload columns in an index unless the table changes slowly enough that an index-only scan is likely to not need to access the heap. If the heap tuple must be visited anyway, it costs nothing more to get the column's value from there. Other restrictions are that expressions are not currently supported as included columns, and that only B-tree and GiST indexes currently support included columns.

Before WarehousePG supported the INCLUDE feature, covering indexes were created by including the payload columns as ordinary index columns, for example:

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```
CREATE INDEX tab_x_y ON tab(x, y);
```

even though they had no intention of ever using `y` as part of a `WHERE` clause. This works fine as long as the extra columns are trailing columns. However, this method doesn't support the case where you want the index to enforce uniqueness on the key column(s).

Suffix truncation always removes non-key columns from upper B-Tree levels. As payload columns, they are never used to guide index scans. The truncation process also removes one or more trailing key column(s) when the remaining prefix of key column(s) happens to be sufficient to describe tuples on the lowest B-Tree level. In practice, covering indexes without an `INCLUDE` clause often avoid storing columns that are effectively payload in the upper levels. However, explicitly defining payload columns as non-key columns reliably keeps the tuples in upper levels small.

In principle, index-only scans can be used with expression indexes. For example, given an index on `f(x)` where `x` is a table column, it should be possible to execute

```
SELECT f(x) FROM tab WHERE f(x) < 1;
```

as an index-only scan; and this is very attractive if `f()` is an expensive-to-compute function. However, WarehousePG's planner is currently not very smart about such cases. It considers a query to be potentially executable by index-only scan only when all columns required by the query are available from the index. In this example, `x` is not needed except in the context `f(x)`, but the planner does not notice that and concludes that an index-only scan is not possible. If an index-only scan seems sufficiently worthwhile, you can work around this by adding `x` as an included column, for example:

```
CREATE INDEX tab_f_x ON tab (f(x)) INCLUDE (x);
```

An additional caveat, if the goal is to avoid recalculating `f(x)`, is that the planner won't necessarily match uses of `f(x)` that aren't in indexable `WHERE` clauses to the index column. It will usually get this right in simple queries such as shown above, but not in queries that involve joins.

Partial indexes also have interesting interactions with index-only scans. Consider the following partial index:

```
CREATE UNIQUE INDEX tests_success_constraint ON tests (subject, target)
    WHERE success;
```

In principle, WarehousePG could perform an index-only scan on this index to satisfy a query like:

```
SELECT target FROM tests WHERE subject = 'some-subject' AND success;
```

But there is a problem: the `WHERE` clause refers to success which is not available as a result column of the index. Nonetheless, an index-only scan is possible because the plan does not need to recheck that part of the `WHERE` clause at run time: all entries found in the index necessarily have `success = true` so this need not be explicitly checked in the plan. WarehousePG version 7 recognizes such cases and generates index-only scans, but older versions do not.

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4.4.9.1 BRIN Indexes

Use Block Range Index (BRIN) for handling very large tables in which certain columns have some natural correlation with their physical location within the table. BRIN works in terms of block ranges (or page ranges), which are groups of pages that are physically adjacent in the table. BRIN stores summary information for each block range. For example, a table storing a store's sale orders might have a date column on which each order was placed, and most of the time the entries for earlier orders will appear earlier in the table as well; a table storing a ZIP code column might have all codes for a city grouped together naturally.

BRIN indexes can satisfy queries via regular bitmap index scans, and return all tuples in all pages within each range if the summary info stored by the index is consistent with the query conditions. The query executor is in charge of rechecking these tuples and discarding those that do not match the query conditions — in other words, these indexes are lossy. Because a BRIN index is very small, scanning the index adds little overhead compared to a sequential scan, but may avoid scanning large parts of the table that are known not to contain matching tuples.

The specific data that a BRIN index stores, as well as the specific queries that the index will be able to satisfy, depend on the operator class selected for each column of the index. Data types that have a linear sort order can have operator classes that store the minimum and maximum value within each block range, for instance; geometrical types store the bounding box for all the objects in the block range.

The size of the block range is determined at index creation time by the `pages_per_range` storage parameter. The number of index entries is equal to the size of the relation in pages divided by the selected value for `pages_per_range`. Therefore, the smaller the number, the larger the index becomes (because of the need to store more index entries), but at the same time the summary data stored can be more precise and more data blocks can be skipped during an index scan. The default value for `pages_per_range` is 32 for heap tables, and 1 for append-optimized tables.

Index Maintenance

At the time of creation, WarehousePG scans all existing heap pages and creates a summary index tuple for each range, including the possibly-incomplete range at the end. As new pages are filled with data, page ranges that are already summarized will cause the summary information to be updated with data from the new tuples. When a new page is created that does not fall within the last summarized range, the range that the new page belongs into does not automatically acquire a summary tuple; those tuples remain unsummarized until a summarization run is invoked later, creating the initial summary for that range.

There are several ways to trigger the initial summarization of a page range. If the table is vacuumed, all existing unsummarized page ranges are summarized.

You may use the following functions:

`brin_summarize_new_values(regclass)` summarizes all unsummarized ranges; `brin_summarize_range(regclass, bigint)` summarizes only the range containing the given page, if it is unsummarized.

Conversely, you may de-summarize a range using the `brin_desummarize_range(regclass, bigint)` function, which is useful when the index tuple is no longer a very good representation because the existing values have changed.

The following table lists the functions available for index maintenance tasks. You cannot execute these functions cannot during recovery. Use of these functions is restricted to superusers and the owner of the given index.

Name	Return Type	Description
brin_summarize_new_values(index regclass)	integer	summarize page ranges not already summarized
brin_summarize_range(index regclass, blockNumber bigint)	integer	summarize the page range covering the given block, if not already summarized
brin_desummarize_range(index regclass, blockNumber bigint)	integer	de-summarize the page range covering the given block, if summarized

`brin_summarize_new_values` accepts the OID or name of a BRIN index and inspects the index to find page ranges in the base table that are not currently summarized by the index; for any such range it creates a new summary index tuple by scanning the table pages. It returns the number of new page range summaries that were inserted into the index. `brin_summarize_range` does the same, except it only summarizes the range that covers the given block number.

> **Note** `brin_summarize_range` and `brin_desummarize_range` only operate on ranges that exist. If you provide a block number that does not exist in the table, the functions return 0. Additionally, a specific range may only exist on some segments, due to data skew. In this case, the functions return the number of segments for which they were able to summarize or desummarize the range.

Built-in Operator Classes

WarehousePG includes the BRIN operator classes shown in the table below.

The `minmax` operator classes store the minimum and the maximum values appearing in the indexed column within the range. The `inclusion` operator classes store a value which includes the values in the indexed column within the range.

Name	Indexed Data Type	Indexable Operators
int8_minmax_ops	bigint	`< <= = >= >`
bit_minmax_ops	bit	`< <= = >= >`
varbit_minmax_ops	bit varying	`< <= = >= >`
box_inclusion_ops	box	`<< &< && <> >> ~= @> <@ &< << >> &>`
bytea_minmax_ops	bytea	`< <= = >= >`
bpchar_minmax_ops	character	`< <= = >= >`
char_minmax_ops	"char"	`< <= = >= >`
date_minmax_ops	date	`< <= = >= >`
float8_minmax_ops	double precision	`< <= = >= >`
inet_minmax_ops	inet	`< <= = >= >`
network_inclusion_ops	inet	`&& >>= <<= = >> <<`
int4_minmax_ops	integer	`< <= = >= >`
interval_minmax_ops	interval	`< <= = >= >`
macaddr_minmax_ops	macaddr	`< <= = >= >`
macaddr8_minmax_op	macaddr8	`< <= = >= >`
name_minmax_ops	name	`< <= = >= >`
numeric_minmax_ops	numeric	`< <= = >= >`

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Name	Indexed Data Type	Indexable Operators	
pg_lsn_minmax_ops	pg_lsn	`< <= = >= >`	
oid_minmax_ops	oid	`< <= = >= >`	
range_inclusion_ops	any range type	`<< &< && <> >> @> <@ -	- = < <= = > >=`
float4_minmax_ops	real	`< <= = >= >`	
int2_minmax_ops	smallint	`< <= = >= >`	
text_minmax_ops	text	`< <= = >= >`	
tid_minmax_ops	tid	`< <= = >= >`	
timestamp_minmax_ops	timestamp without time zone	`< <= = >= >`	
timestamptz_minmax_ops	timestamp with time zone	`< <= = >= >`	
time_minmax_ops	time without time zone	`< <= = >= >`	
timetz_minmax_ops	time with time zone	`< <= = >= >`	
uuid_minmax_ops	uuid	`< <= = >= >`	

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4.4.10 Creating and Managing Views

Views enable you to save frequently used or complex queries, then access them in a `SELECT` statement as if they were a table. A view is not physically materialized on disk: the query runs as a subquery when you access the view.

These topics describe various aspects of creating and managing views:

- Best Practices when Creating Views outlines best practices when creating views.
- Working with View Dependencies contains examples of listing view information and determining what views depend on a certain object.
- About View Storage in WarehousePG describes the mechanics behind view dependencies.

Creating Views

The `CREATE VIEW` command defines a view of a query. For example:

```
CREATE VIEW comedies AS SELECT * FROM films WHERE kind = 'comedy';
```

Views ignore `ORDER BY` and `SORT` operations stored in the view.

Dropping Views

The `DROP VIEW` command removes a view. For example:

```
DROP VIEW topten;
```

The `DROP VIEW...CASCADE` command also removes all dependent objects. As an example, if another view depends on the view which is about to be dropped, the other view will be dropped as well. Without the `CASCADE` option, the `DROP VIEW` command will fail.

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4.4.10.1 Best Practices when Creating Views

When defining and using a view, remember that a view is just an SQL statement and is replaced by its definition when the query is run.

These are some common uses of views.

- They allow you to have a recurring SQL query or expression in one place for easy reuse.
- They can be used as an interface to abstract from the actual table definitions, so that you can reorganize the tables without having to modify the interface.

If a subquery is associated with a single query, consider using the `WITH` clause of the `SELECT` command instead of creating a seldom-used view.

In general, these uses do not require nesting views, that is, defining views based on other views.

These are two patterns of creating views that tend to be problematic because the view's SQL is used during query execution.

- Defining many layers of views so that your final queries look deceptively simple.

  Problems arise when you try to enhance or troubleshoot queries that use the views, for example by examining the execution plan. The query's execution plan tends to be complicated and it is difficult to understand and how to improve it.

- Defining a denormalized "world" view. A view that joins a large number of database tables that is used for a wide variety of queries.

  Performance issues can occur for some queries that use the view for some `WHERE` conditions while other `WHERE` conditions work well.

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4.4.10.2 Working with View Dependencies

If there are view dependencies on a table you must use the `CASCADE` keyword to drop it. Also, you cannot alter the table if there are view dependencies on it. This example shows a view dependency on a table.

```
CREATE TABLE t (id integer PRIMARY KEY);
CREATE VIEW v AS SELECT * FROM t;

DROP TABLE t;
ERROR:  cannot drop table t because other objects depend on it
DETAIL:  view v depends on table t
HINT:  Use DROP ... CASCADE to drop the dependent objects too.

ALTER TABLE t DROP id;
ERROR:  cannot drop column id of table t because other objects depend on it
DETAIL:  view v depends on column id of table t
HINT:  Use DROP ... CASCADE to drop the dependent objects too.
```

As the previous example shows, altering a table can be quite a challenge if there is a deep hierarchy of views, because you have to create the views in the correct order. You cannot create a view unless all the objects it requires are present.

You can use view dependency information when you want to alter a table that is referenced by a view. For example, you might want to change a table's column data type from `integer` to `bigint` because you realize you need to store larger numbers. However, you cannot do that if there are views that use the column. You first have to drop those views, then change the column and then run all the `CREATE VIEW` statements to create the views again.

Finding View Dependencies

The following example queries list view information on dependencies on tables and columns.

- Finding Direct View Dependencies on a Table
- Finding Direct Dependencies on a Table Column
- Listing View Schemas
- Listing View Definitions
- Listing Nested Views

The example output is based on the Example Data at the end of this topic.

Also, you can use the first example query Finding Direct View Dependencies on a Table to find dependencies on user-defined functions (or procedures). The query uses the catalog table `pg_class` that contains information about tables and views. For functions, you can use the catalog table `pg_proc` to get information about functions.

For detailed information about the system catalog tables that store view information, see About View Storage in WarehousePG.

Finding Direct View Dependencies on a Table

To find out which views directly depend on table `t1`, create a query that performs a join among the catalog tables that contain the dependency information, and qualify the query to return only view dependencies.

```
SELECT v.oid::regclass AS view,
  d.refobjid::regclass AS ref_object    -- name of table
  -- d.refobjid::regproc AS ref_object  -- name of function
FROM pg_depend AS d      -- objects that depend on a table
  JOIN pg_rewrite AS r  -- rules depending on a table
     ON r.oid = d.objid
  JOIN pg_class AS v    -- views for the rules
     ON v.oid = r.ev_class
WHERE v.relkind = 'v'         -- filter views only
  -- dependency must be a rule depending on a relation
  AND d.classid = 'pg_rewrite'::regclass
  AND d.deptype = 'n'         -- normal dependency
  -- qualify object
  AND d.refclassid = 'pg_class'::regclass   -- dependent table
  AND d.refobjid = 't1'::regclass
  -- AND d.refclassid = 'pg_proc'::regclass -- dependent function
  -- AND d.refobjid = 'f'::regproc
;
    view    | ref_object
------------+------------
 v1         | t1
 v2         | t1
 v2         | t1
 v3         | t1
 mytest.vt1 | t1
 mytest.v2a | t1
 mytest.v2a | t1
(7 rows)
```

The query performs casts to the `regclass` object identifier type. For information about object identifier types, see the PostgeSQL documentation on Object Identifier Types.

In some cases, the views are listed multiple times because the view references multiple table columns. You can remove those duplicates using `DISTINCT`.

You can alter the query to find views with direct dependencies on the function `f`.

- In the `SELECT` clause replace the name of the table `d.refobjid::regclass as ref_object` with the name of the function `d.refobjid::regproc as ref_object`
- In the `WHERE` clause replace the catalog of the referenced object from `d.refclassid = 'pg_class'::regclass` for tables, to `d.refclassid = 'pg_proc'::regclass` for procedures (functions). Also change the object name from `d.refobjid = 't1'::regclass` to `d.refobjid = 'f'::regproc`
- In the `WHERE` clause, replace the name of the table `refobjid = 't1'::regclass` with the name of the function `refobjid = 'f'::regproc`.

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In the example query, the changes have been commented out (prefixed with `--`). You can comment out the lines for the table and enable the lines for the function.

Finding Direct Dependencies on a Table Column

You can modify the previous query to find those views that depend on a certain table column, which can be useful if you are planning to drop a column (adding a column to the base table is never a problem). The query uses the table column information in the `pg_attribute` catalog table.

This query finds the views that depend on the column `id` of table `t1`:

```
SELECT v.oid::regclass AS view,
  d.refobjid::regclass AS ref_object, -- name of table
  a.attname AS col_name               -- column name
FROM pg_attribute AS a   -- columns for a table
  JOIN pg_depend AS d    -- objects that depend on a column
    ON d.refobjsubid = a.attnum AND d.refobjid = a.attrelid
  JOIN pg_rewrite AS r   -- rules depending on the column
    ON r.oid = d.objid
  JOIN pg_class AS v     -- views for the rules
    ON v.oid = r.ev_class
WHERE v.relkind = 'v'    -- filter views only
  -- dependency must be a rule depending on a relation
  AND d.classid = 'pg_rewrite'::regclass
  AND d.refclassid = 'pg_class'::regclass
  AND d.deptype = 'n'    -- normal dependency
  AND a.attrelid = 't1'::regclass
  AND a.attname = 'id'
;
    view    | ref_object | col_name
------------+------------+----------
 v1         | t1         | id
 v2         | t1         | id
 mytest.vt1 | t1         | id
 mytest.v2a | t1         | id
(4 rows)
```

Listing View Schemas

If you have created views in multiple schemas, you can also list views, each view's schema, and the table referenced by the view. The query retrieves the schema from the catalog table `pg_namespace` and excludes the system schemas `pg_catalog`, `information_schema`, and `gp_toolkit`. Also, the query does not list a view if the view refers to itself.

```
SELECT v.oid::regclass AS view,
  ns.nspname AS schema,       -- view schema,
  d.refobjid::regclass AS ref_object -- name of table
FROM pg_depend AS d            -- objects that depend on a table
  JOIN pg_rewrite AS r         -- rules depending on a table
    ON r.oid = d.objid
  JOIN pg_class AS v           -- views for the rules
    ON v.oid = r.ev_class
  JOIN pg_namespace AS ns      -- schema information
    ON ns.oid = v.relnamespace
WHERE v.relkind = 'v'          -- filter views only
  -- dependency must be a rule depending on a relation
  AND d.classid = 'pg_rewrite'::regclass
  AND d.refclassid = 'pg_class'::regclass  -- referenced objects in pg_class -- tables and views
  AND d.deptype = 'n'          -- normal dependency
  -- qualify object
  AND ns.nspname NOT IN ('pg_catalog', 'information_schema', 'gp_toolkit') -- system schemas
  AND NOT (v.oid = d.refobjid) -- not self-referencing dependency
;
    view    | schema | ref_object
------------+--------+------------
 v1         | public | t1
 v2         | public | t1
 v2         | public | t1
 v2         | public | v1
 v3         | public | t1
 vm1        | public | mytest.tm1
 mytest.vm1 | mytest | t1
 vm2        | public | mytest.tm1
 mytest.v2a | mytest | t1
 mytest.v2a | mytest | t1
 mytest.v2a | mytest | v1
(11 rows)
```

Listing View Definitions

This query lists the views that depend on `t1`, the column referenced, and the view definition. The `CREATE VIEW` command is created by adding the appropriate text to the view definition.

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```
SELECT v.relname AS view,
  d.refobjid::regclass as ref_object,
  d.refobjsubid as ref_col,
  'CREATE VIEW ' || v.relname || ' AS ' || pg_get_viewdef(v.oid) AS view_def
FROM pg_depend AS d
  JOIN pg_rewrite AS r
    ON r.oid = d.objid
  JOIN pg_class AS v
    ON v.oid = r.ev_class
WHERE NOT (v.oid = d.refobjid)
  AND d.refobjid = 't1'::regclass
  ORDER BY d.refobjsubid
;
 view | ref_object | ref_col |                  view_def
------+------------+---------+---------------------------------------------
 v1   | t1         |       1 | CREATE VIEW v1 AS  SELECT max(t1.id) AS id+
      |            |         |    FROM t1;
 v2a  | t1         |       1 | CREATE VIEW v2a AS  SELECT t1.val         +
      |            |         |    FROM (t1                               +
      |            |         |      JOIN v1 USING (id));
 vt1  | t1         |       1 | CREATE VIEW vt1 AS  SELECT t1.id          +
      |            |         |    FROM t1                                +
      |            |         |   WHERE (t1.id < 3);
 v2   | t1         |       1 | CREATE VIEW v2 AS  SELECT t1.val          +
      |            |         |    FROM (t1                               +
      |            |         |      JOIN v1 USING (id));
 v2a  | t1         |       2 | CREATE VIEW v2a AS  SELECT t1.val         +
      |            |         |    FROM (t1                               +
      |            |         |      JOIN v1 USING (id));
 v3   | t1         |       2 | CREATE VIEW v3 AS  SELECT (t1.val || f()) +
      |            |         |    FROM t1;
 v2   | t1         |       2 | CREATE VIEW v2 AS  SELECT t1.val          +
      |            |         |    FROM (t1                               +
      |            |         |      JOIN v1 USING (id));
(7 rows)
```

Listing Nested Views

This CTE query lists information about views that reference another view.

The `WITH` clause in this CTE query selects all the views in the user schemas. The main `SELECT` statement finds all views that reference another view.

```
WITH views AS ( SELECT v.relname AS view,
  d.refobjid AS ref_object,
  v.oid AS view_oid,
  ns.nspname AS namespace
FROM pg_depend AS d
  JOIN pg_rewrite AS r
    ON r.oid = d.objid
  JOIN pg_class AS v
    ON v.oid = r.ev_class
  JOIN pg_namespace AS ns
    ON ns.oid = v.relnamespace
WHERE v.relkind = 'v'
  AND ns.nspname NOT IN ('pg_catalog', 'information_schema', 'gp_toolkit') -- exclude system schemas
  AND d.deptype = 'n'    -- normal dependency
  AND NOT (v.oid = d.refobjid) -- not a self-referencing dependency
 )
SELECT views.view, views.namespace AS schema,
  views.ref_object::regclass AS ref_view,
  ref_nspace.nspname AS ref_schema
FROM views
  JOIN pg_depend as dep
    ON dep.refobjid = views.view_oid
  JOIN pg_class AS class
    ON views.ref_object = class.oid
  JOIN  pg_namespace AS ref_nspace
     ON class.relnamespace = ref_nspace.oid
  WHERE class.relkind = 'v'
    AND dep.deptype = 'n'
;
 view | schema | ref_view | ref_schema
------+--------+----------+------------
 v2   | public | v1       | public
 v2a  | mytest | v1       | public
```

Example Data

The output for the example queries is based on these database objects and data.

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```
CREATE TABLE t1 (
   id integer PRIMARY KEY,
   val text NOT NULL
);

INSERT INTO t1 VALUES
   (1, 'one'), (2, 'two'), (3, 'three');

CREATE FUNCTION f() RETURNS text
   LANGUAGE sql AS 'SELECT ''suffix''::text';

CREATE VIEW v1 AS
  SELECT max(id) AS id
  FROM t1;

CREATE VIEW v2 AS
  SELECT t1.val
  FROM t1 JOIN v1 USING (id);

CREATE VIEW v3 AS
  SELECT val || f()
  FROM t1;

CREATE VIEW v5 AS
  SELECT f() ;

CREATE SCHEMA mytest ;

CREATE TABLE mytest.tm1 (
   id integer PRIMARY KEY,
   val text NOT NULL
);

INSERT INTO mytest.tm1 VALUES
   (1, 'one'), (2, 'two'), (3, 'three');

CREATE VIEW vm1 AS
  SELECT id FROM mytest.tm1 WHERE id < 3 ;

CREATE VIEW mytest.vm1 AS
  SELECT id FROM public.t1 WHERE id < 3 ;

CREATE VIEW vm2 AS
  SELECT max(id) AS id
  FROM mytest.tm1;

CREATE VIEW mytest.v2a AS
  SELECT t1.val
  FROM public.t1 JOIN public.v1 USING (id);
```

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4.4.10.3 About View Storage in WarehousePG

A view is similar to a table, both are relations - that is "something with columns". All such objects are stored in the catalog table `pg_class`. These are the general differences:

- A view has no data files (because it holds no data).
- The value of `pg_class.relkind` for a view is `v` rather than `r`.
- A view has an `ON SELECT` query rewrite rule called `_RETURN`.

  The rewrite rule contains the definition of the view and is stored in the `ev_action` column of the `pg_rewrite` catalog table.

For more technical information about views, see the PostgreSQL documentation aboutViews and the Rule System.

Also, a view definition is *not* stored as a string, but in the form of a query parse tree. Views are parsed when they are created, which has several consequences:

- Object names are resolved during `CREATE VIEW`, so the current setting of `search_path` affects the view definition.
- Objects are referred to by their internal immutable object ID rather than by their name. Consequently, renaming an object or column referenced in a view definition can be performed without dropping the view.
- WarehousePG can determine exactly which objects are used in the view definition, so it can add dependencies on them.

Note that the way WarehousePG handles views is quite different from the way WarehousePG handles functions: function bodies are stored as strings and are not parsed when they are created. Consequently, WarehousePG does not know on which objects a given function depends.

Where View Dependency Information is Stored

These system catalog tables contain the information used to determine the tables on which a view depends.

- `pg_class` - object information including tables and views. The `relkind` column describes the type of object.
- `pg_depend` - object dependency information for database-specific (non-shared) objects.
- `pg_rewrite` - rewrite rules for tables and views.
- `pg_attribute` - information about table columns.
- `pg_namespace` - information about schemas (namespaces).

It is important to note that there is no direct dependency of a view on the objects it uses: the dependent object is actually the view's rewrite rule. That adds another layer of indirection to view dependency information.

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4.4.11 Creating and Managing Materialized Views

Materialized views are similar to views. A materialized view enables you to save a frequently used or complex query, then access the query results in a `SELECT` statement as if they were a table. Materialized views persist the query results in a table-like form. While access to the data stored in a materialized view can be much faster than accessing the underlying tables directly or through a view, the data is not always current.

The materialized view data cannot be directly updated. To refresh the materialized view data, use the `REFRESH MATERIALIZED VIEW` command. The query used to create the materialized view is stored in exactly the same way that a view's query is stored. For example, you can create a materialized view that quickly displays a summary of historical sales data for situations where having incomplete data for the current date would be acceptable.

```
CREATE MATERIALIZED VIEW sales_summary AS
  SELECT seller_no, invoice_date, sum(invoice_amt)::numeric(13,2) as sales_amt
    FROM invoice
    WHERE invoice_date < CURRENT_DATE
    GROUP BY seller_no, invoice_date
    ORDER BY seller_no, invoice_date;

CREATE UNIQUE INDEX sales_summary_seller
  ON sales_summary (seller_no, invoice_date);
```

The materialized view might be useful for displaying a graph in the dashboard created for sales people. You could schedule a job to update the summary information each night using this command.

```
REFRESH MATERIALIZED VIEW sales_summary;
```

The information about a materialized view in the WarehousePG cluster catalogs is exactly the same as it is for a table or view. A materialized view is a relation, just like a table or a view. When a materialized view is referenced in a query, the data is returned directly from the materialized view, just like from a table. The query in the materialized view definition is only used for populating the materialized view.

If you can tolerate periodic updates of materialized view data, the performance benefit can be substantial.

One use of a materialized view is to allow faster access to data brought in from an external data source such as external table or a foreign data wrapper. Also, you can define indexes on a materialized view, whereas foreign data wrappers do not support indexes; this advantage might not apply for other types of external data access.

If a subquery is associated with a single query, consider using the `WITH` clause of the `SELECT` command instead of creating a seldom-used materialized view.

Parent topic: DDL: Defining Database Objects

Creating Materialized Views

The `CREATE MATERIALIZED VIEW` command defines a materialized view based on a query.

```
CREATE MATERIALIZED VIEW us_users AS SELECT u.id, u.name, a.zone FROM users u, address a WHERE a.country = 'USA';
```

If a materialized view query contains an `ORDER BY` or `SORT` clause, the clause is ignored when a `SELECT` is performed on the materialized query.

Refreshing or Deactivating Materialized Views

The `REFRESH MATERIALIZED VIEW` command updates the materialized view data.

```
REFRESH MATERIALIZED VIEW us_users;
```

With the `WITH NO DATA` clause, the current data is removed, no new data is generated, and the materialized view is left in an unscannable state. An error is returned if a query attempts to access an unscannable materialized view.

```
REFRESH MATERIALIZED VIEW us_users WITH NO DATA;
```

Dropping Materialized Views

The `DROP MATERIALIZED VIEW` command removes a materialized view definition and data. For example:

```
DROP MATERIALIZED VIEW us_users;
```

The `DROP MATERIALIZED VIEW ... CASCADE` command also removes all dependent objects. For example, if another materialized view depends on the materialized view which is about to be dropped, the other materialized view will be dropped as well. Without the `CASCADE` option, the `DROP MATERIALIZED VIEW` command fails.

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4.5 DML: Inserting, Updating and Deleting

This section provides information about manipulating data and concurrent access in WarehousePG.

This topic includes the following subtopics:

- About Concurrency Control in WarehousePG
- Inserting Rows
- Updating Existing Rows
- Deleting Rows
- Working With Transactions
- Global Deadlock Detector
- Vacuuming the Database
- Running Out of Locks

Parent topic: WarehousePG Administrator Guide

About Concurrency Control in WarehousePG

WarehousePG and PostgreSQL do not use locks for concurrency control. They maintain data consistency using a multiversion model, Multiversion Concurrency Control (MVCC). MVCC achieves transaction isolation for each database session, and each query transaction sees a snapshot of data. This ensures the transaction sees consistent data that is not affected by other concurrent transactions.

Because MVCC does not use explicit locks for concurrency control, lock contention is minimized and WarehousePG maintains reasonable performance in multiuser environments. Locks acquired for querying (reading) data do not conflict with locks acquired for writing data.

WarehousePG provides multiple lock modes to control concurrent access to data in tables. Most WarehousePG SQL commands automatically acquire the appropriate locks to ensure that referenced tables are not dropped or modified in incompatible ways while a command runs. For applications that cannot adapt easily to MVCC behavior, you can use the `LOCK` command to acquire explicit locks. However, proper use of MVCC generally provides better performance.

Lock Mode	Associated SQL Commands	Conflicts With
ACCESS SHARE	`SELECT`	ACCESS EXCLUSIVE
ROW SHARE	`SELECT...FOR lock_strength`	EXCLUSIVE, ACCESS EXCLUSIVE
ROW EXCLUSIVE	`INSERT`, `COPY`	SHARE, SHARE ROW EXCLUSIVE, EXCLUSIVE, ACCESS EXCLUSIVE
SHARE UPDATE EXCLUSIVE	`VACUUM` (without `FULL`), `ANALYZE`	SHARE UPDATE EXCLUSIVE, SHARE, SHARE ROW EXCLUSIVE, EXCLUSIVE, ACCESS EXCLUSIVE
SHARE	`CREATE INDEX`	ROW EXCLUSIVE, SHARE UPDATE EXCLUSIVE, SHARE ROW EXCLUSIVE, EXCLUSIVE, ACCESS EXCLUSIVE
SHARE ROW EXCLUSIVE		ROW EXCLUSIVE, SHARE UPDATE EXCLUSIVE, SHARE, SHARE ROW EXCLUSIVE, EXCLUSIVE, ACCESS EXCLUSIVE
EXCLUSIVE	`DELETE`, `UPDATE`, `SELECT...FOR lock_strength`, `REFRESH MATERIALIZED VIEW CONCURRENTLY`	ROW SHARE, ROW EXCLUSIVE, SHARE UPDATE EXCLUSIVE, SHARE, SHARE ROW EXCLUSIVE, EXCLUSIVE, ACCESS EXCLUSIVE
ACCESS EXCLUSIVE	`ALTER TABLE`, `DROP TABLE`, `TRUNCATE`, `REINDEX`, `CLUSTER`, `REFRESH MATERIALIZED VIEW` (without `CONCURRENTLY`), `VACUUM FULL`	ACCESS SHARE, ROW SHARE, ROW EXCLUSIVE, SHARE UPDATE EXCLUSIVE, SHARE, SHARE ROW EXCLUSIVE, EXCLUSIVE, ACCESS EXCLUSIVE

> **Note** By default, the Global Deadlock Detector is deactivated, and WarehousePG acquires the more restrictive `EXCLUSIVE` lock (rather than `ROW EXCLUSIVE` in PostgreSQL) for `UPDATE`, `DELETE`, and `SELECT` queries with a locking clause (`FOR lock_strength`).

When the Global Deadlock Detector is enabled:

- The lock mode for some `DELETE` and `UPDATE` operations on heap tables is `ROW EXCLUSIVE`. See Global Deadlock Detector.
- The lock mode for some queries with a locking clause (`SELECT...FOR lock_strength`) is `ROW SHARE`. See "The Locking Clause" in SELECT.

Inserting Rows

Use the `INSERT` command to create rows in a table. This command requires the table name and a value for each column in the table; you may optionally specify the column names in any order. If you do not specify column names, list the data values in the order of the columns in the table, separated by commas.

For example, to specify the column names and the values to insert:

```
INSERT INTO products (name, price, product_no) VALUES ('Cheese', 9.99, 1);
```

To specify only the values to insert:

```
INSERT INTO products VALUES (1, 'Cheese', 9.99);
```

Usually, the data values are literals (constants), but you can also use scalar expressions. For example:

```
INSERT INTO films SELECT * FROM tmp_films WHERE date_prod <
'2016-05-07';
```

You can insert multiple rows in a single command. For example:

```
INSERT INTO products (product_no, name, price) VALUES
    (1, 'Cheese', 9.99),
    (2, 'Bread', 1.99),
    (3, 'Milk', 2.99);
```

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To insert data into a partitioned table, you specify the root partitioned table, which is the table created with the `CREATE TABLE` command. You also can specify a leaf partition in an `INSERT` command. An error is returned if the data is not valid for the specified leaf partition. Specifying a table that is not a leaf partition in the `INSERT` command is not supported.

To insert large amounts of data, use external tables or the `COPY` command. These load mechanisms are more efficient than `INSERT` for inserting large quantities of rows. See Loading and Unloading Data for more information about bulk data loading.

The storage model of append-optimized tables is optimized for bulk data loading. WarehousePG does not recommend single row `INSERT` statements for append-optimized tables. For append-optimized tables, WarehousePG supports a maximum of 127 concurrent `INSERT` transactions into a single append-optimized table.

Updating Existing Rows

The `UPDATE` command updates rows in a table. You can update all rows, a subset of all rows, or individual rows in a table. You can update each column separately without affecting other columns.

To perform an update, you need:

- The name of the table and columns to update
- The new values of the columns
- One or more conditions specifying the row or rows to be updated.

For example, the following command updates all products that have a price of *5* to have a price of *10*:

```
UPDATE products SET price = 10 WHERE price = 5;
```

Using `UPDATE` in WarehousePG has the following restrictions:

- While GPORCA supports updates to WarehousePG distribution key columns, the Postgres-based planner does not.
- If mirrors are enabled, you cannot use `STABLE` or `VOLATILE` functions in an `UPDATE` statement.
- WarehousePG partitioning columns cannot be updated.

Deleting Rows

The `DELETE` command deletes rows from a table. Specify a `WHERE` clause to delete rows that match certain criteria. If you do not specify a `WHERE` clause, all rows in the table are deleted. The result is a valid, but empty, table. For example, to remove all rows from the products table that have a price of *10*:

```
DELETE FROM products WHERE price = 10;
```

To delete all rows from a table:

```
DELETE FROM products;
```

Using `DELETE` in WarehousePG has similar restrictions to using `UPDATE`:

- If mirrors are enabled, you cannot use `STABLE` or `VOLATILE` functions in an `UPDATE` statement.

Truncating a Table

Use the `TRUNCATE` command to quickly remove all rows in a table. For example:

```
TRUNCATE mytable;
```

This command empties a table of all rows in one operation. Note that `TRUNCATE` does not scan the table, therefore it does not process inherited child tables or `ON DELETE` rewrite rules. The command truncates only rows in the named table.

Working With Transactions

Transactions allow you to bundle multiple SQL statements in one all-or-nothing operation.

The following are the WarehousePG SQL transaction commands:

- `BEGIN` or `START TRANSACTION` starts a transaction block.
- `END` or `COMMIT` commits the results of a transaction.
- `ROLLBACK` abandons a transaction without making any changes.
- `SAVEPOINT` marks a place in a transaction and enables partial rollback. You can roll back commands run after a savepoint while maintaining commands run before the savepoint.
- `ROLLBACK TO SAVEPOINT` rolls back a transaction to a savepoint.
- `RELEASE SAVEPOINT` destroys a savepoint within a transaction.

Transaction Isolation Levels

WarehousePG accepts the standard SQL transaction levels as follows:

- `READ UNCOMMITTED` and `READ COMMITTED` behave like the standard `READ COMMITTED`.
- `REPEATABLE READ` and `SERIALIZABLE` behave like `REPEATABLE READ`.

The following information describes the behavior of the WarehousePG transaction levels.

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Read Uncommitted and Read Committed

WarehousePG does not allow any command to see an uncommitted update in another concurrent transaction, so `READ UNCOMMITTED` behaves the same as `READ COMMITTED`. `READ COMMITTED` provides fast, simple, partial transaction isolation. `SELECT`, `UPDATE`, and `DELETE` commands operate on a snapshot of the database taken when the query started.

A `SELECT` query:

- Sees data committed before the query starts.
- Sees updates run within the transaction.
- Does not see uncommitted data outside the transaction.
- Can possibly see changes that concurrent transactions made if the concurrent transaction is committed after the initial read in its own transaction.

Successive `SELECT` queries in the same transaction can see different data if other concurrent transactions commit changes between the successive queries. `UPDATE` and `DELETE` commands find only rows committed before the commands started.

`READ COMMITTED` transaction isolation allows concurrent transactions to modify or lock a row before `UPDATE` or `DELETE` find the row. `READ COMMITTED` transaction isolation may be inadequate for applications that perform complex queries and updates and require a consistent view of the database.

Repeatable Read and Serializable

`SERIALIZABLE` transaction isolation, as defined by the SQL standard, ensures that transactions that run concurrently produce the same results as if they were run one after another. If you specify `SERIALIZABLE` WarehousePG falls back to `REPEATABLE READ`. `REPEATABLE READ` transactions prevent dirty reads, non-repeatable reads, and phantom reads without expensive locking, but WarehousePG does not detect all serializability interactions that can occur during concurrent transaction execution. Concurrent transactions should be examined to identify interactions that are not prevented by disallowing concurrent updates of the same data. You can prevent these interactions by using explicit table locks or by requiring the conflicting transactions to update a dummy row introduced to represent the conflict.

With `REPEATABLE READ` transactions, a `SELECT` query:

- Sees a snapshot of the data as of the start of the transaction (not as of the start of the current query within the transaction).
- Sees only data committed before the query starts.
- Sees updates run within the transaction.
- Does not see uncommitted data outside the transaction.
- Does not see changes that concurrent transactions make.
- Successive `SELECT` commands within a single transaction always see the same data.
- `UPDATE`, `DELETE`, `SELECT FOR UPDATE`, and `SELECT FOR SHARE` commands find only rows committed before the command started. If a concurrent transaction has updated, deleted, or locked a target row, the `REPEATABLE READ` transaction waits for the concurrent transaction to commit or roll back the change. If the concurrent transaction commits the change, the `REPEATABLE READ` transaction rolls back. If the concurrent transaction rolls back its change, the `REPEATABLE READ` transaction can commit its changes.

The default transaction isolation level in WarehousePG is `READ COMMITTED`. To change the isolation level for a transaction, declare the isolation level when you `BEGIN` the transaction or use the `SET TRANSACTION` command after the transaction starts.

Global Deadlock Detector

The WarehousePG Global Deadlock Detector background worker process collects lock information on all segments and uses a directed algorithm to detect the existence of local and global deadlocks. This algorithm allows WarehousePG to relax concurrent update and delete restrictions on heap tables. (WarehousePG still employs table-level locking on AO/CO tables, restricting concurrent `UPDATE`, `DELETE`, and `SELECT...FOR lock_strength` operations.)

By default, the Global Deadlock Detector is deactivated and WarehousePG runs the concurrent `UPDATE` and `DELETE` operations on a heap table serially. You can activate these concurrent updates and have the Global Deadlock Detector determine when a deadlock exists by setting the server configuration parameter `gp_enable_global_deadlock_detector`.

When the Global Deadlock Detector is enabled, the background worker process is automatically started on the coordinator host when you start WarehousePG. You configure the interval at which the Global Deadlock Detector collects and analyzes lock waiting data via the gp_global_deadlock_detector_period server configuration parameter.

If the Global Deadlock Detector determines that deadlock exists, it breaks the deadlock by cancelling one or more backend processes associated with the youngest transaction(s) involved.

When the Global Deadlock Detector determines a deadlock exists for the following types of transactions, only one of the transactions will succeed. The other transactions will fail with an error indicating that concurrent updates to the same row is not allowed.

- Concurrent transactions on the same row of a heap table where the first transaction is an update operation and a later transaction runs an update or delete and the query plan contains a motion operator.
- Concurrent update transactions on the same distribution key of a heap table that are run by the Postgres-based planner.
- Concurrent update transactions on the same row of a hash table that are run by the GPORCA optimizer.

> **Note** WarehousePG uses the interval specified in the deadlock_timeout server configuration parameter for local deadlock detection. Because the local and global deadlock detection algorithms differ, the cancelled process(es) may differ depending upon which detector (local or global) WarehousePG triggers first.

> **Note** If the lock_timeout server configuration parameter is turned on and set to a value smaller than `deadlock_timeout` and `gp_global_deadlock_detector_period`, WarehousePG will cancel a statement before it would ever trigger a deadlock check in that session.

To view lock waiting information for all segments, run the `gp_dist_wait_status()` user-defined function. You can use the output of this function to determine which transactions are waiting on locks, which transactions are holding locks, the lock types and mode, the waiter and holder session identifiers, and which segments are running the transactions. Sample output of the `gp_dist_wait_status()` function follows:

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```
SELECT * FROM pg_catalog.gp_dist_wait_status();
-[ RECORD 1 ]----+--------------
segid            | 0
waiter_dxid      | 11
holder_dxid      | 12
holdTillEndXact  | t
waiter_lpid      | 31249
holder_lpid      | 31458
waiter_lockmode  | ShareLock
waiter_locktype  | transactionid
waiter_sessionid | 8
holder_sessionid | 9
-[ RECORD 2 ]----+--------------
segid            | 1
waiter_dxid      | 12
holder_dxid      | 11
holdTillEndXact  | t
waiter_lpid      | 31467
holder_lpid      | 31250
waiter_lockmode  | ShareLock
waiter_locktype  | transactionid
waiter_sessionid | 9
holder_sessionid | 8
```

When it cancels a transaction to break a deadlock, the Global Deadlock Detector reports the following error message:

```
ERROR:  canceling statement due to user request: "cancelled by global deadlock detector"
```

Global Deadlock Detector UPDATE and DELETE Compatibility

The Global Deadlock Detector can manage concurrent updates for these types of `UPDATE` and `DELETE` commands on heap tables:

- Simple `UPDATE` of a single table. Update a non-distribution key with the Postgres-based planner. The command does not contain a `FROM` clause, or a sub-query in the `WHERE` clause.

  ```
  UPDATE t SET c2 = c2 + 1 WHERE c1 > 10;
  ```

- Simple `DELETE` of a single table. The command does not contain a sub-query in the `FROM` or `WHERE` clauses.

  ```
  DELETE FROM t WHERE c1 > 10;
  ```

- Split `UPDATE`. For the Postgres-based planner, the `UPDATE` command updates a distribution key.

  ```
  UPDATE t SET c = c + 1; -- c is a distribution key
  ```

  For GPORCA, the `UPDATE` command updates a distribution key or references a distribution key.

  ```
  UPDATE t SET b = b + 1 WHERE c = 10; -- c is a distribution key
  ```

- Complex `UPDATE`. The `UPDATE` command includes multiple table joins.

  ```
  UPDATE t1 SET c = t1.c+1 FROM t2 WHERE t1.c = t2.c;
  ```

  Or the command contains a sub-query in the `WHERE` clause.

  ```
  UPDATE t SET c = c + 1 WHERE c > ALL(SELECT * FROM t1);
  ```

- Complex `DELETE`. A complex `DELETE` command is similar to a complex `UPDATE`, and involves multiple table joins or a sub-query.

  ```
  DELETE FROM t USING t1 WHERE t.c > t1.c;
  ```

The following table shows the concurrent `UPDATE` or `DELETE` commands that are managed by the Global Deadlock Detector. For example, concurrent simple `UPDATE` commands on the same table row are managed by the Global Deadlock Detector. For a concurrent complex `UPDATE` and a simple `UPDATE`, only one `UPDATE` is performed, and an error is returned for the other `UPDATE`.

Command	Simple `UPDATE`	Simple `DELETE`	Split `UPDATE`	Complex `UPDATE`	Complex `DELETE`
Simple `UPDATE`	YES	YES	NO	NO	NO
Simple `DELETE`	YES	YES	NO	YES	YES
Split `UPDATE`	NO	NO	NO	NO	NO
Complex `UPDATE`	NO	YES	NO	NO	NO
Complex `DELETE`	NO	YES	NO	NO	YES

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Vacuuming the Database

Deleted or updated data rows occupy physical space on disk even though new transactions cannot see them. Periodically running the `VACUUM` command removes these expired rows. For example:

```
VACUUM mytable;
```

The `VACUUM` command collects table-level statistics such as the number of rows and pages. Vacuum all tables after loading data, including append-optimized tables. For information about recommended routine vacuum operations, see Routine Vacuum and Analyze.

> **Important** The `VACUUM`, `VACUUM FULL`, and `VACUUM ANALYZE` commands should be used to maintain the data in a WarehousePG especially if updates and deletes are frequently performed on your database data. See the `VACUUM` command in the *WarehousePG Reference Guide* for information about using the command.

Running Out of Locks

WarehousePG can potentially run out of locks when a database operation accesses multiple tables in a single transaction. Backup and restore are examples of such operations.

When WarehousePG runs out of locks, the error message that you may observe references a shared memory error:

```
... "WARNING","53200","out of shared memory",,,,,,"LOCK TABLE ...
... "ERROR","53200","out of shared memory",,"You might need to increase max_locks_per_transaction.",,,,"LOCK TABLE ...
```

> **Note** "shared memory" in this context refers to the shared memory of the internal object: the lock slots. "Out of shared memory" does *not* refer to exhaustion of system- or WarehousePG-level memory resources.

As the hint describes, consider increasing the `max_locks_per_transaction` server configuration parameter when you encounter this error.

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4.6 Querying Data

This topic provides information about using SQL in WarehousePGs.

You enter SQL statements called queries to view, change, and analyze data in a database using the `psql` interactive SQL client and other client tools.

- **About WarehousePG Query Processing**
  This topic provides an overview of how WarehousePG processes queries. Understanding this process can be useful when writing and tuning queries.
- **About GPORCA**
  In WarehousePG, the default GPORCA optimizer co-exists with the Postgres-based planner.
- **Defining Queries**
  WarehousePG is based on the PostgreSQL implementation of the SQL standard.
- **WITH Queries (Common Table Expressions)**
  The `WITH` clause provides a way to use subqueries or perform a data modifying operation in a larger `SELECT` query. You can also use the `WITH` clause in an `INSERT`, `UPDATE`, or `DELETE` command.
- **Using Functions and Operators**
  Description of user-defined and built-in functions and operators in WarehousePG.
- **Working with JSON Data**
  WarehousePG supports the `json` and `jsonb` data types that store JSON (JavaScript Object Notation) data.
- **Working with XML Data**
  WarehousePG supports the `xml` data type that stores XML data.
- **Using Full Text Search**
  WarehousePG provides data types, functions, operators, index types, and configurations for querying natural language documents.
- **Query Performance**
  WarehousePG dynamically eliminates irrelevant partitions in a table and optimally allocates memory for different operators in a query.
- **Managing Spill Files Generated by Queries**
  WarehousePG creates spill files, also known as workfiles, on disk if it does not have sufficient memory to run an SQL query in memory.
- **Query Profiling**
  Examine the query plans of poorly performing queries to identify possible performance tuning opportunities.
- **Just-in-Time Compilation (JIT)** WarehousePG supports Just-in-Time compilation for long-running CPU-bound queries.

Parent topic: WarehousePG Administrator Guide

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4.6.1 About WarehousePG Query Processing

This topic provides an overview of how WarehousePG processes queries. Understanding this process can be useful when writing and tuning queries.

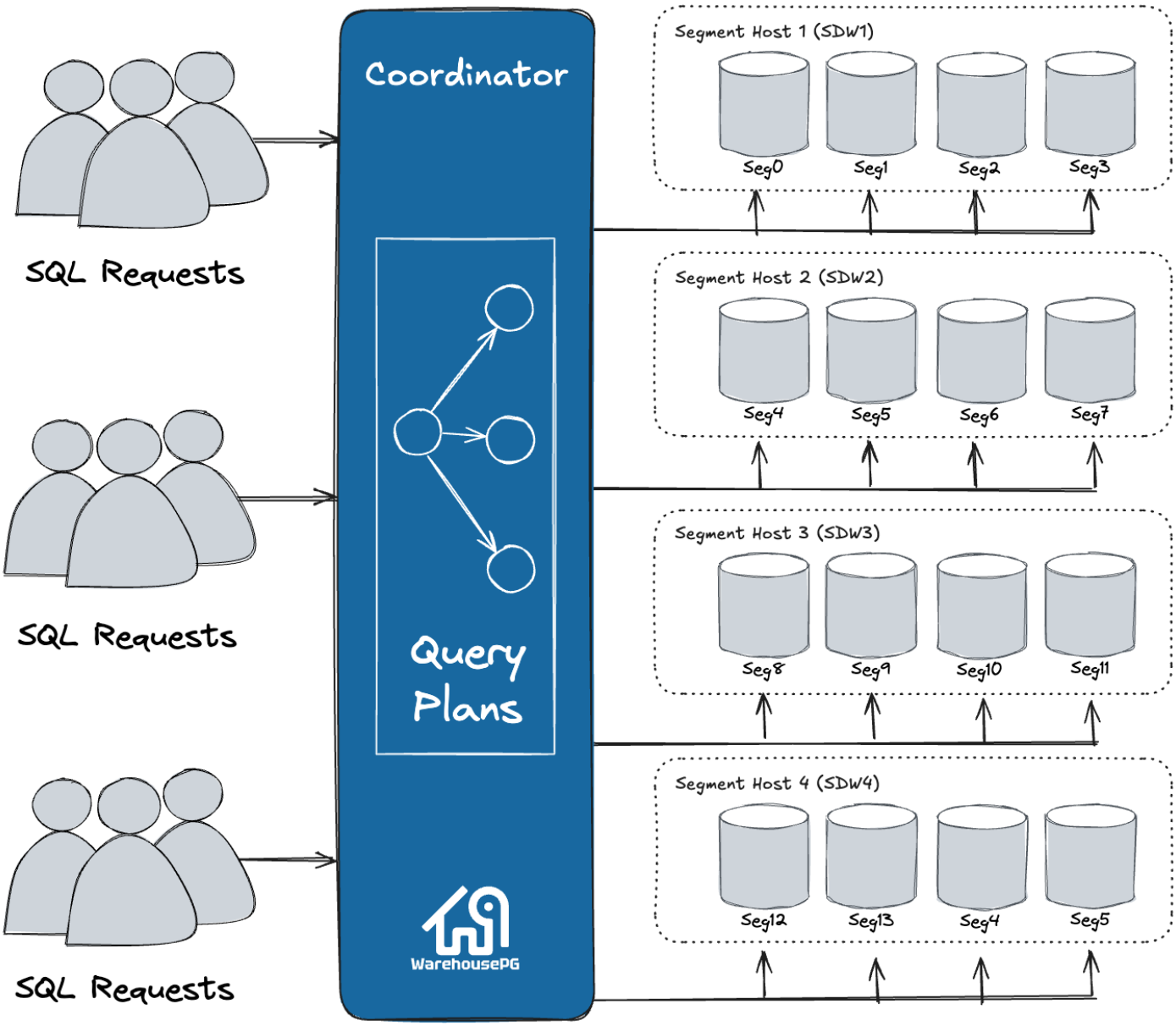
Users issue queries to WarehousePG as they would to any database management system. They connect to the database instance on the WarehousePG coordinator host using a client application such as `psql` and submit SQL statements.

Parent topic: Querying Data

Understanding Query Planning and Dispatch

The coordinator receives, parses, and optimizes the query. The resulting query plan is either parallel or targeted. The coordinator dispatches parallel query plans to all data segments.

Dispatched Parallel Query Plan



The coordinator dispatches targeted query plans to a single segment. Each segment is responsible for running local database operations on its own set of data. Most database operations—such as table scans, joins, aggregations, and sorts—run across all segments in parallel. Each operation is performed on a segment database independent of the data stored in the other segment databases.

Dispatched Targeted Query Plan

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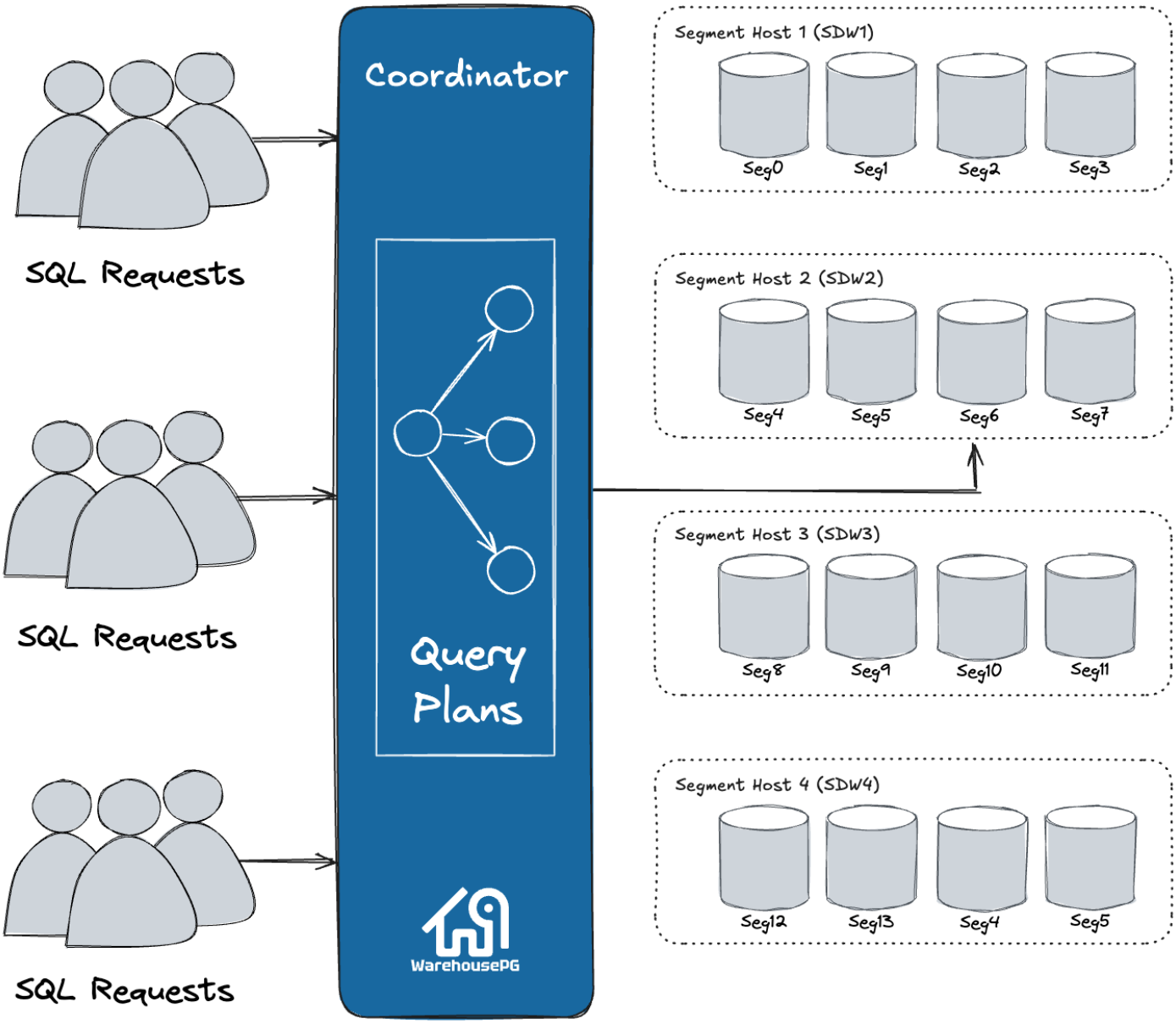

Certain queries may access only data on a single segment, such as single-row `INSERT`, `UPDATE`, `DELETE`, or `SELECT` operations or queries that filter on the table distribution key column(s). In queries such as these, the query plan is not dispatched to all segments, but is targeted at the segment that contains the affected or relevant row(s).

Understanding WarehousePG Query Plans

A query plan is the set of operations WarehousePG will perform to produce the answer to a query. Each *node* or step in the plan represents a database operation such as a table scan, join, aggregation, or sort. Plans are read and run from bottom to top.

In addition to common database operations such as table scans, joins, and so on, WarehousePG has an additional operation type called *motion*. A motion operation involves moving tuples between the segments during query processing. Note that not every query requires a motion. For example, a targeted query plan does not require data to move across the interconnect.

To achieve maximum parallelism during query runtime, WarehousePG divides the work of the query plan into *slices*. A slice is a portion of the plan that segments can work on independently. A query plan is sliced wherever a *motion* operation occurs in the plan, with one slice on each side of the motion.

For example, consider the following simple query involving a join between two tables:

```
SELECT customer, amount
FROM ww_sales JOIN customer USING (cust_id)
WHERE dateCol = '04-30-2025';
```

The following figure shows the query plan. Each segment receives a copy of the query plan and works on it in parallel.

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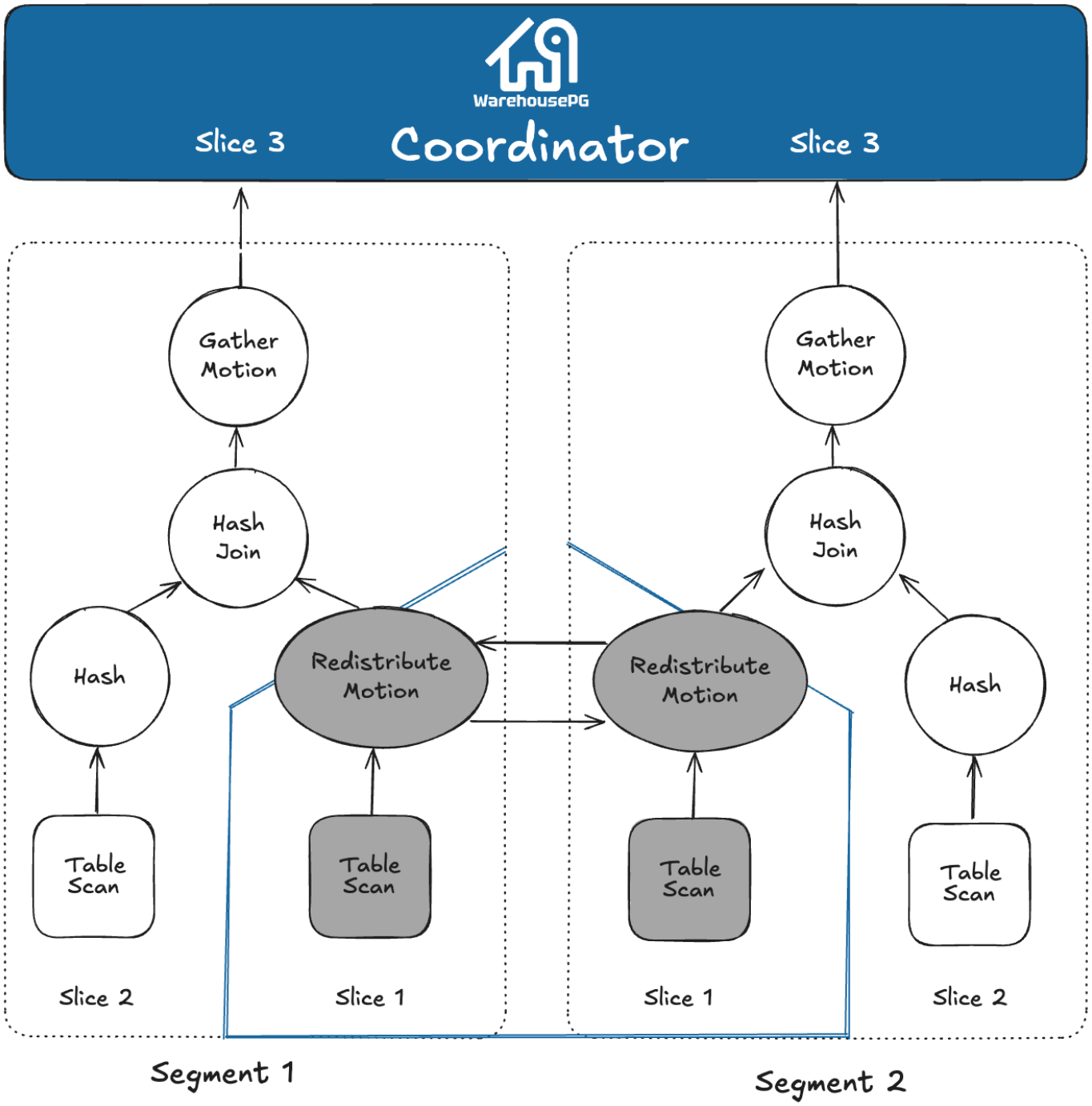

The query plan for this example has a *redistribute motion* that moves tuples between the segments to complete the join. The redistribute motion is necessary because the customer table is distributed across the segments by `cust_id`, but the sales table is distributed across the segments by `sale_id`. To perform the join, the `sales` tuples must be redistributed by `cust_id`. The plan is sliced on either side of the redistribute motion, creating *slice 1* and *slice 2*.

This query plan has another type of motion operation called a *gather motion*. A gather motion is when the segments send results back up to the coordinator for presentation to the client. Because a query plan is always sliced wherever a motion occurs, this plan also has an implicit slice at the very top of the plan (*slice 3*). Not all query plans involve a gather motion. For example, a `CREATE TABLE x AS SELECT...` statement would not have a gather motion because tuples are sent to the newly created table, not to the coordinator.

Understanding Parallel Query Execution

WarehousePG creates a number of database processes to handle the work of a query. On the coordinator, the query worker process is called the *query dispatcher* (QD). The QD is responsible for creating and dispatching the query plan. It also accumulates and presents the final results. On the segments, a query worker process is called a *query executor* (QE). A QE is responsible for completing its portion of work and communicating its intermediate results to the other worker processes.

There is at least one worker process assigned to each *slice* of the query plan. A worker process works on its assigned portion of the query plan independently. During query runtime, each segment will have a number of processes working on the query in parallel.

Related processes that are working on the same slice of the query plan but on different segments are called *gangs*. As a portion of work is completed, tuples flow up the query plan from one gang of processes to the next. This inter-process communication between the segments is referred to as the *interconnect* component of WarehousePG.

The following figure shows the query worker processes on the coordinator and two segment instances for previous query plan.

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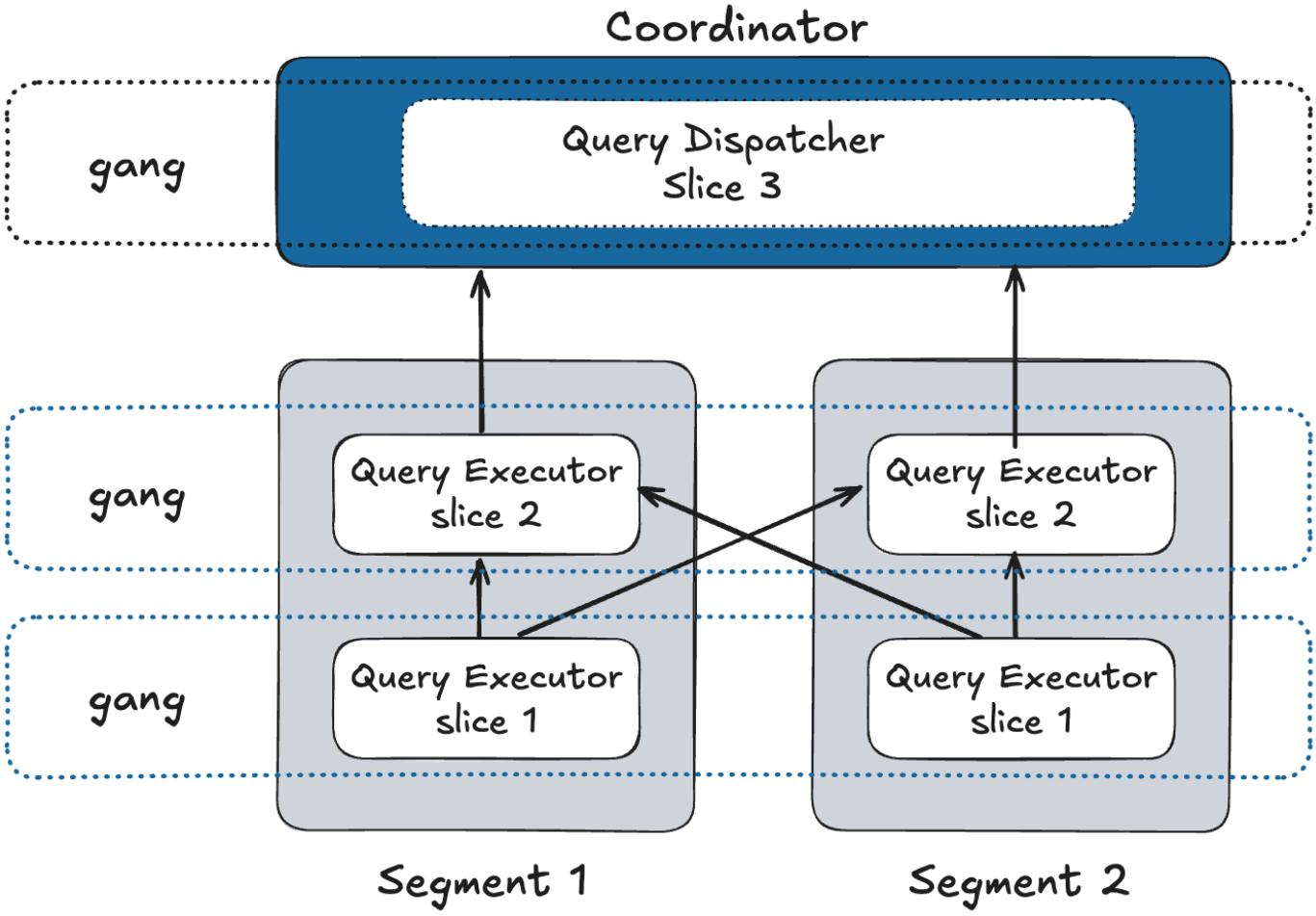

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4.6.2 About GPORCA

In WarehousePG, the default GPORCA optimizer co-exists with the Postgres-based planner.

- **Overview of GPORCA**
  GPORCA extends the planning and optimization capabilities of the Postgres-based planner.
- **Activating and Deactivating GPORCA**
  By default, WarehousePG uses GPORCA instead of the Postgres-based planner. Server configuration parameters activate or deactivate GPORCA.
- **Collecting Root Partition Statistics**
  For a partitioned table, GPORCA uses statistics of the table root partition to generate query plans. These statistics are used for determining the join order, for splitting and joining aggregate nodes, and for costing the query steps. In contrast, the Postgres-based planner uses the statistics of each leaf partition.
- **Considerations when Using GPORCA**
  To run queries optimally with GPORCA, consider the query criteria closely.
- **GPORCA Features and Enhancements**
  GPORCA, the WarehousePG next generation query optimizer, includes enhancements for specific types of queries and operations:
- **Changed Behavior with GPORCA**
  There are changes to WarehousePG behavior with the GPORCA optimizer enabled (the default) as compared to the Postgres-based planner.
- **GPORCA Limitations**
  There are limitations in WarehousePG when using the default GPORCA optimizer. GPORCA and the Postgres-based planner currently coexist in WarehousePG because GPORCA does not support all WarehousePG features.
- **Determining the Query Optimizer that is Used**
  When GPORCA is enabled (the default), you can determine if WarehousePG is using GPORCA or is falling back to the Postgres-based planner.

Parent topic: Querying Data

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4.6.2.1 Overview of GPORCA

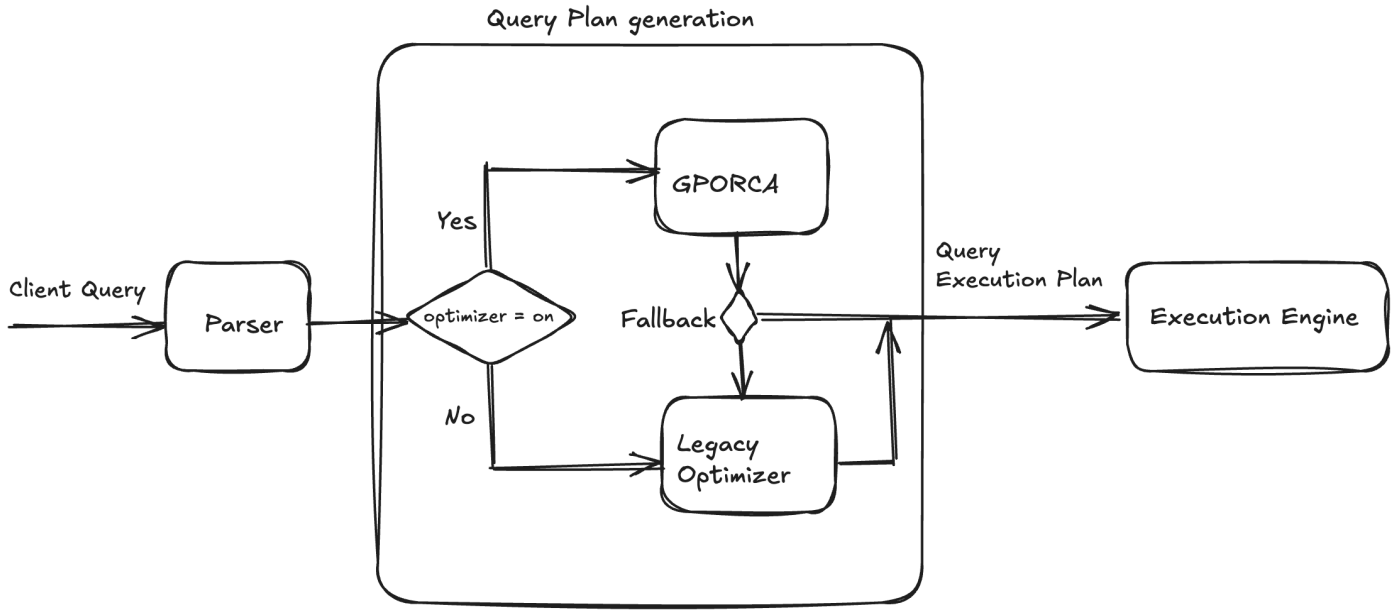
GPORCA extends the planning and optimization capabilities of the Postgres-based planner.GPORCA is extensible and achieves better optimization in multi-core architecture environments. WarehousePG uses GPORCA by default to generate an execution plan for a query when possible.

GPORCA also enhances WarehousePG query performance tuning in the following areas:

- Queries against partitioned tables
- Queries that contain a common table expression (CTE)
- Queries that contain subqueries

In WarehousePG, GPORCA co-exists with the Postgres-based planner. By default, WarehousePG uses GPORCA. If GPORCA cannot be used, then the Postgres-based planner is used.

The following figure shows how GPORCA fits into the query planning architecture.



Note All Postgres-based planner server configuration parameters are ignored by GPORCA. However, if WarehousePG falls back to the Postgres-based planner, the planner server configuration parameters will impact the query plan generation. For a list of Postgres-based planner server configuration parameters, see Query Tuning Parameters.

Parent topic: About GPORCA

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4.6.2.2 Activating and Deactivating GPORCA

By default, WarehousePG uses GPORCA instead of the Postgres-based planner. Server configuration parameters activate or deactivate GPORCA.

Although GPORCA is on by default, you can configure GPORCA usage at the system, database, session, or query level using the optimizer parameter. Refer to one of the following sections if you want to change the default behavior:

- Enabling GPORCA for a System
- Enabling GPORCA for a Database
- Enabling GPORCA for a Session or a Query

> **Note** You can deactivate the ability to activate or deactivate GPORCA with the server configuration parameter optimizer_control. For information about the server configuration parameters, see the *WarehousePG Reference Guide*.

Parent topic: About GPORCA

Enabling GPORCA for a System

Set the server configuration parameter optimizer for the WarehousePG cluster.

1. Log into the WarehousePG coordinator host as `gpadmin`, the WarehousePG administrator.
2. Set the values of the server configuration parameters. These WarehousePG gpconfig utility commands sets the value of the parameters to `on`:

   ```
   $ gpconfig -c optimizer -v on --coordinatoronly
   ```

3. Restart WarehousePG. This WarehousePG gpstop utility command reloads the `postgresql.conf` files of the coordinator and segments without shutting down WarehousePG.

   ```
   gpstop -u
   ```

Enabling GPORCA for a Database

Set the server configuration parameter optimizer for individual WarehousePGs with the ALTER DATABASE command. For example, this command enables GPORCA for the database *test_db*.

```
> ALTER DATABASE test_db SET OPTIMIZER = ON ;
```

Enabling GPORCA for a Session or a Query

You can use the SET command to set optimizer server configuration parameter for a session. For example, after you use the psql utility to connect to WarehousePG, this SET command enables GPORCA:

```
> set optimizer = on ;
```

To set the parameter for a specific query, include the SET command prior to running the query.

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4.6.2.3 Collecting Root Partition Statistics

For a partitioned table, GPORCA uses statistics of the table root partition to generate query plans. These statistics are used for determining the join order, for splitting and joining aggregate nodes, and for costing the query steps. In contrast, the Postgres-based planner uses the statistics of each leaf partition.

If you run queries on partitioned tables, you should collect statistics on the root partition and periodically update those statistics to ensure that GPORCA can generate optimal query plans. If the root partition statistics are not up-to-date or do not exist, GPORCA still performs dynamic partition elimination for queries against the table. However, the query plan might not be optimal.

Parent topic: About GPORCA

Running ANALYZE

By default, running the `ANALYZE` command on a root partitioned table samples the leaf partition data in the table, and stores the statistics for the root partition. `ANALYZE` collects statistics on the root and leaf partitions, including HyperLogLog (HLL) statistics on the leaf partitions. `ANALYZE ROOTPARTITION` collects statistics only on the root partition. The server configuration parameter optimizer_analyze_root_partition controls whether the `ROOTPARTITION` keyword is required to collect root statistics for a root partitioned table. See the ANALYZE command for information about collecting statistics on partitioned tables.

Keep in mind that `ANALYZE` always scans the entire table before updating the root partition statistics. If your table is very large, this operation can take a significant amount of time. `ANALYZE ROOTPARTITION` also uses an `ACCESS SHARE` lock that prevents certain operations, such as `TRUNCATE` and `VACUUM` operations, during runtime. For these reasons, you should schedule `ANALYZE` operations periodically, or when there are significant changes to leaf partition data.

Follow these best practices for running `ANALYZE` or `ANALYZE ROOTPARTITION` on partitioned tables in your system:

- Run `ANALYZE <root_partition_table_name>` on a new partitioned table after adding initial data. Run `ANALYZE <leaf_partition_table_name>` on a new leaf partition or a leaf partition where data has changed. By default, running the command on a leaf partition updates the root partition statistics if the other leaf partitions have statistics.
- Update root partition statistics when you observe query performance regression in `EXPLAIN` plans against the table, or after significant changes to leaf partition data. For example, if you add a new leaf partition at some point after generating root partition statistics, consider running `ANALYZE` or `ANALYZE ROOTPARTITION` to update root partition statistics with the new tuples inserted from the new leaf partition.
- For very large tables, run `ANALYZE` or `ANALYZE ROOTPARTITION` only weekly, or at some interval longer than daily.
- Avoid running `ANALYZE` with no arguments, because doing so runs the command on all database tables including partitioned tables. With large databases, these global `ANALYZE` operations are difficult to monitor, and it can be difficult to predict the time needed for completion.
- Consider running multiple `ANALYZE <table_name>` or `ANALYZE ROOTPARTITION <table_name>` operations in parallel to speed the operation of statistics collection, if your I/O throughput can support the load.
- You can also use the WarehousePG utility `analyzedb` to update table statistics. Using `analyzedb` ensures that tables that were previously analyzed are not re-analyzed if no modifications were made to the leaf partition.

GPORCA and Leaf Partition Statistics

Although creating and maintaining root partition statistics is crucial for GPORCA query performance with partitioned tables, maintaining leaf partition statistics is also important. If GPORCA cannot generate a plan for a query against a partitioned table, then the Postgres-based planner is used and leaf partition statistics are needed to produce the optimal plan for that query.

GPORCA itself also uses leaf partition statistics for any queries that access leaf partitions directly, instead of using the root partition with predicates to eliminate partitions. For example, if you know which partitions hold necessary tuples for a query, you can directly query the leaf partition itself; in this case GPORCA uses the leaf partition statistics.

Deactivating Automatic Root Partition Statistics Collection

If you do not intend to run queries on partitioned tables with GPORCA (setting the server configuration parameter optimizer to `off`), then you can deactivate the automatic collection of statistics on the root partition of the partitioned table. The server configuration parameter optimizer_analyze_root_partition controls whether the `ROOTPARTITION` keyword is required to collect root statistics for a root partitioned table. The default setting for the parameter is `on`, the `ANALYZE` command can collect root partition statistics without the `ROOTPARTITION` keyword. You can deactivate automatic collection of root partition statistics by setting the parameter to `off`. When the value is `off`, you must run `ANALZYE ROOTPARTITION` to collect root partition statistics.

1. Log into the WarehousePG coordinator host as `gpadmin`, the WarehousePG administrator.
2. Set the values of the server configuration parameters. These WarehousePG `gpconfig` utility commands sets the value of the parameters to `off`:

   ```
   $ gpconfig -c optimizer_analyze_root_partition -v off --coordinatoronly
   ```

3. Restart WarehousePG. This WarehousePG `gpstop` utility command reloads the `postgresql.conf` files of the coordinator and segments without shutting down WarehousePG.

   ```
   gpstop -u
   ```

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4.6.2.4 Considerations when Using GPORCA

To run queries optimally with GPORCA, consider the query criteria closely.

Ensure the following criteria are met:

- The table does not contain multi-column partition keys.
- The server configuration parameter `optimizer_enable_coordinator_only_queries` is set to `on` when running against coordinator only tables such as the system table *pg_attribute*. For information about the parameter, see the *WarehousePG Reference Guide*.

  > **Note** Enabling this parameter decreases performance of short running catalog queries. To avoid this issue, set this parameter only for a session or a query.

- Statistics have been collected on the root partitioned table.

If the partitioned table contains more than 20,000 partitions, consider a redesign of the table schema.

These server configuration parameters affect GPORCA query processing.

- `optimizer_cte_inlining_bound` controls the amount of inlining performed for common table expression (CTE) queries (queries that contain a `WITH` clause).
- `optimizer_force_comprehensive_join_implementation` affects GPORCA's consideration of nested loop join and hash join alternatives. When the value is `false` (the default), GPORCA does not consider nested loop join alternatives when a hash join is available.
- `optimizer_force_multistage_agg` forces GPORCA to choose a multi-stage aggregate plan for a scalar distinct qualified aggregate. When the value is `off` (the default), GPORCA chooses between a one-stage and two-stage aggregate plan based on cost.
- `optimizer_force_three_stage_scalar_dqa` forces GPORCA to choose a plan with multistage aggregates when such a plan alternative is generated.
- `optimizer_join_order` sets the query optimization level for join ordering by specifying which types of join ordering alternatives to evaluate.
- `optimizer_join_order_threshold` specifies the maximum number of join children for which GPORCA uses the dynamic programming-based join ordering algorithm.
- `optimizer_nestloop_factor` controls nested loop join cost factor to apply to during query optimization.
- `optimizer_parallel_union` controls the amount of parallelization that occurs for queries that contain a `UNION` or `UNION ALL` clause. When the value is `on`, GPORCA can generate a query plan of the child operations of a `UNION` or `UNION ALL` operation run in parallel on segment instances.
- `optimizer_sort_factor` controls the cost factor that GPORCA applies to sorting operations during query optimization. The cost factor can be adjusted for queries when data skew is present.
- `gp_enable_relsize_collection` controls how GPORCA (and the Postgres-based planner) handle a table without statistics. By default, GPORCA uses a default value to estimate the number of rows if statistics are not available. When this value is `on`, GPORCA uses the estimated size of a table if there are no statistics for the table.

  This parameter is ignored for a root partitioned table. If the root partition does not have statistics, GPORCA always uses the default value. You can use `ANALZYE ROOTPARTITION` to collect statistics on the root partition. See ANALYZE.

These server configuration parameters control the display and logging of information.

- `optimizer_print_missing_stats` controls the display of column information about columns with missing statistics for a query (default is `true`)
- `optimizer_print_optimization_stats` controls the logging of GPORCA query optimization metrics for a query (default is `off`)

For information about the parameters, see the *WarehousePG Reference Guide*.

GPORCA generates minidumps to describe the optimization context for a given query. The minidump files are used by support to analyze WarehousePG issues. The information in the file is not in a format that can be easily used for debugging or troubleshooting. The minidump file is located under the coordinator data directory and uses the following naming format:

```
Minidump_date_time.mdp
```

For information about the minidump file, see the server configuration parameter `optimizer_minidump` in the *WarehousePG Reference Guide*.

When the `EXPLAIN ANALYZE` command uses GPORCA, the `EXPLAIN` plan shows only the number of partitions that are being eliminated. The scanned partitions are not shown. To show the name of the scanned partitions in the segment logs set the server configuration parameter `gp_log_dynamic_partition_pruning` to `on`. This example `SET` command enables the parameter.

```
SET gp_log_dynamic_partition_pruning = on;
```

Parent topic: About GPORCA

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4.6.2.5 GPORCA Features and Enhancements

GPORCA, the WarehousePG next generation query optimizer, includes enhancements for specific types of queries and operations:

- Queries Against Partitioned Tables
- Queries that Contain Subqueries
- Queries that Contain Common Table Expressions
- DML Operation Enhancements with GPORCA

GPORCA also includes these optimization enhancements:

- Improved join ordering
- Join-Aggregate reordering
- Sort order optimization
- Data skew estimates included in query optimization

Parent topic: About GPORCA

Queries Against Partitioned Tables

GPORCA includes these enhancements for queries against partitioned tables:

- Partition elimination is improved.
- Query plan can contain the Partition selector operator.
- Partitions are not enumerated in EXPLAIN plans.

  For queries that involve static partition selection where the partitioning key is compared to a constant, GPORCA lists the number of partitions to be scanned in the `EXPLAIN` output under the Partition Selector operator. This example Partition Selector operator shows the filter and number of partitions selected:

  ```
  Partition Selector for Part_Table (dynamic scan id: 1)
         Filter: a > 10
         Partitions selected:  1 (out of 3)
  ```

  For queries that involve dynamic partition selection where the partitioning key is compared to a variable, the number of partitions that are scanned will be known only during query execution. The partitions selected are not shown in the `EXPLAIN` output.
- Plan size is independent of number of partitions.
- Out of memory errors caused by number of partitions are reduced.

This example CREATE TABLE command creates a range partitioned table.

```
CREATE TABLE sales(order_id int, item_id int, amount numeric(15,2),
      date date, yr_qtr int)
   PARTITION BY RANGE (yr_qtr) (start (201501) INCLUSIVE end (201504) INCLUSIVE,
   start (201601) INCLUSIVE end (201604) INCLUSIVE,
   start (201701) INCLUSIVE end (201704) INCLUSIVE,
   start (201801) INCLUSIVE end (201804) INCLUSIVE,
   start (201901) INCLUSIVE end (201904) INCLUSIVE,
   start (202001) INCLUSIVE end (202004) INCLUSIVE);
```

GPORCA improves on these types of queries against partitioned tables:

- Full table scan. Partitions are not enumerated in plans.

  ```
  SELECT * FROM sales;
  ```
- Query with a constant filter predicate. Partition elimination is performed.

  ```
  SELECT * FROM sales WHERE yr_qtr = 201501;
  ```
- Range selection. Partition elimination is performed.

  ```
  SELECT * FROM sales WHERE yr_qtr BETWEEN 201601 AND 201704 ;
  ```
- Joins involving partitioned tables. In this example, the partitioned dimension table *date_dim* is joined with fact table *catalog_sales*:

  ```
  SELECT * FROM catalog_sales
     WHERE date_id IN (SELECT id FROM date_dim WHERE month=12);
  ```

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Queries that Contain Subqueries

GPORCA handles subqueries more efficiently. A subquery is query that is nested inside an outer query block. In the following query, the SELECT in the WHERE clause is a subquery.

```
SELECT * FROM part
  WHERE price > (SELECT avg(price) FROM part);
```

GPORCA also handles queries that contain a correlated subquery (CSQ) more efficiently. A correlated subquery is a subquery that uses values from the outer query. In the following query, the `price` column is used in both the outer query and the subquery.

```
SELECT * FROM part p1 WHERE price > (SELECT avg(price) FROM part p2 WHERE p2.brand = p1.brand);
```

GPORCA generates more efficient plans for the following types of subqueries:

- CSQ in the SELECT list.

  ```
  SELECT *,
   (SELECT min(price) FROM part p2 WHERE p1.brand = p2.brand)
   AS foo
  FROM part p1;
  ```

- CSQ in disjunctive (OR) filters.

  ```
  SELECT FROM part p1 WHERE p_size > 40 OR
        p_retailprice >
        (SELECT avg(p_retailprice)
            FROM part p2
            WHERE p2.p_brand = p1.p_brand)
  ```

- Nested CSQ with skip level correlations

  ```
  SELECT * FROM part p1 WHERE p1.p_partkey
  IN (SELECT p_partkey FROM part p2 WHERE p2.p_retailprice =
       (SELECT min(p_retailprice)
         FROM part p3
         WHERE p3.p_brand = p1.p_brand)
  );
  ```

  Note Nested CSQ with skip level correlations are not supported by the Postgres-based planner.

- CSQ with aggregate and inequality. This example contains a CSQ with an inequality.

  ```
  SELECT * FROM part p1 WHERE p1.p_retailprice =
   (SELECT min(p_retailprice) FROM part p2 WHERE p2.p_brand <> p1.p_brand);
  ```

- CSQ that must return one row.

  ```
  SELECT p_partkey,
    (SELECT p_retailprice FROM part p2 WHERE p2.p_brand = p1.p_brand )
  FROM part p1;
  ```

Queries that Contain Common Table Expressions

GPORCA handles queries that contain the WITH clause. The WITH clause, also known as a common table expression (CTE), generates temporary tables that exist only for the query. This example query contains a CTE.

```
WITH v AS (SELECT a, sum(b) as s FROM T where c < 10 GROUP BY a)
  SELECT *FROM  v AS v1 ,  v AS v2
  WHERE v1.a <> v2.a AND v1.s < v2.s;
```

As part of query optimization, GPORCA can push down predicates into a CTE. For example query, GPORCA pushes the equality predicates to the CTE.

```
WITH v AS (SELECT a, sum(b) as s FROM T GROUP BY a)
  SELECT *
  FROM v as v1, v as v2, v as v3
  WHERE v1.a < v2.a
    AND v1.s < v3.s
    AND v1.a = 10
    AND v2.a = 20
    AND v3.a = 30;
```

GPORCA can handle these types of CTEs:

- CTE that defines one or multiple tables. In this query, the CTE defines two tables.

  ```
  WITH cte1 AS (SELECT a, sum(b) as s FROM T
                where c < 10 GROUP BY a),
       cte2 AS (SELECT a, s FROM cte1 where s > 1000)
    SELECT *
    FROM cte1 as v1, cte2 as v2, cte2 as v3
    WHERE v1.a < v2.a AND v1.s < v3.s;
  ```

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- Nested CTEs.

```
WITH v AS (WITH w AS (SELECT a, b FROM foo
                      WHERE b < 5)
           SELECT w1.a, w2.b
           FROM w AS w1, w AS w2
           WHERE w1.a = w2.a AND w1.a > 2)
  SELECT v1.a, v2.a, v2.b
  FROM v as v1, v as v2
  WHERE v1.a < v2.a;
```

DML Operation Enhancements with GPORCA

GPORCA contains enhancements for DML operations such as INSERT, UPDATE, and DELETE.

- A DML node in a query plan is a query plan operator.
    - Can appear anywhere in the plan, as a regular node (top slice only for now)
    - Can have consumers
- UPDATE operations use the query plan operator Split and supports these operations:
    - UPDATE operations on the table distribution key columns.
    - UPDATE operations on the table on the partition key column. This example plan shows the Split operator.

```
QUERY PLAN
------------------------------------------------------------------
Update  (cost=0.00..5.46 rows=1 width=1)
   ->  Redistribute Motion 2:2  (slice1; segments: 2)
         Hash Key: a
         ->  Result  (cost=0.00..3.23 rows=1 width=48)
               ->  Split  (cost=0.00..2.13 rows=1 width=40)
                     ->  Result  (cost=0.00..1.05 rows=1 width=40)
                           ->  Seq Scan on dmltest
```

- New query plan operator Assert is used for constraints checking.

  This example plan shows the Assert operator.

```
QUERY PLAN
------------------------------------------------------------------
 Insert  (cost=0.00..4.61 rows=3 width=8)
   ->  Assert  (cost=0.00..3.37 rows=3 width=24)
         Assert Cond: (dmlsource.a > 2) IS DISTINCT FROM
false
         ->  Assert  (cost=0.00..2.25 rows=3 width=24)
               Assert Cond: NOT dmlsource.b IS NULL
               ->  Result  (cost=0.00..1.14 rows=3 width=24)
                     ->  Seq Scan on dmlsource
```

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4.6.2.6 Changed Behavior with GPORCA

There are changes to WarehousePG behavior with the GPORCA optimizer enabled (the default) as compared to the Postgres-based planner.

- UPDATE operations on distribution keys are allowed.
- UPDATE operations on partitioned keys are allowed.
- Queries against uniform partitioned tables are supported.
- The command CREATE TABLE AS distributes table data randomly if the DISTRIBUTED BY clause is not specified and no primary or unique keys are specified.
- Non-deterministic updates not allowed. The following UPDATE command returns an error.

```
update r set b =  r.b  + 1 from s where  r.a  in (select a from s);
```

- Statistics are required on the root table of a partitioned table. The ANALYZE command generates statistics on both the root partitioned table and individual leaf partitions. See the ROOTPARTITION clause for ANALYZE command.
- Additional Result nodes in the query plan:
    - Query plan Assert operator.
    - Query plan Partition selector operator.
    - Query plan Split operator.
- When running EXPLAIN, the query plan generated by GPORCA is different than the plan generated by the Postgres-based planner.
- WarehousePG adds the log file message `Planner produced plan` when GPORCA is enabled and WarehousePG falls back to the Postgres-based planner to generate the query plan.
- WarehousePG issues a warning when statistics are missing from one or more table columns. When running an SQL command with GPORCA, WarehousePG issues a warning if the command performance could be improved by collecting statistics on a column or set of columns referenced by the command. The warning is issued on the command line and information is added to the WarehousePG log file. For information about collecting statistics on table columns, see the ANALYZE command in the *WarehousePG Reference Guide*.

Parent topic: About GPORCA

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4.6.2.7 GPORCA Limitations

There are limitations in WarehousePG when using the default GPORCA optimizer. GPORCA and the Postgres-based planner currently coexist in WarehousePG because GPORCA does not support all WarehousePG features.

This section describes the limitations.

- Unsupported SQL Query Features
- Performance Regressions

Parent topic: About GPORCA

Unsupported SQL Query Features

Certain query features are not supported with the default GPORCA optimizer. When an unsupported query is run, WarehousePG logs this notice along with the query text:

```
Falling back to Postgres-based planner because GPORCA does not support the following feature: UTILITY command
```

These features are unsupported when GPORCA is enabled (the default):

- SP-GiST indexing method. GPORCA supports only B-tree, bitmap, GIN, and GiST indexes. GPORCA ignores indexes created with unsupported methods.
- The `SELECT` command's `TABLESAMPLE` clause.
- The optional `WITH ORDINALITY` clause of a function call inside the `FROM` clause of a `SELECT` command.
- Multi-level partitioned tables.
- Non-uniform partitioned tables.
- SortMergeJoin (SMJ).
- Ordered aggregations.
- Multi-argument `DISTINCT` qualified aggregates, for example `SELECT corr(DISTINCT a, b) FROM tbl1;`.
- Multiple grouping sets specified using a duplicate alias in a null-producing grouping set spec. Such queries fall back to the Postgres-based planner unless you directly coerce the alias to a separate variable as shown in the example below:

  ```
  CREATE TEMP TABLE tempt AS SELECT i AS ai1, i AS ai2 FROM generate_series(1,
  3)i;
  SELECT ai1, ai2 FROM tempt GROUP BY ai2, ROLLUP(ai1) ORDER BY ai1,
  ai2;
  ```

- These scalar operators:
  - ROW
  - ROWCOMPARE
  - FIELDSELECT
- Aggregate functions that take set operators as input arguments.
- Multiple Distinct Qualified Aggregates, such as `SELECT count(DISTINCT a), sum(DISTINCT b) FROM foo`, are not supported by default. They can be enabled with the `optimizer_enable_multiple_distinct_aggs` Configuration Parameter.
- percentile_* window functions (ordered-set aggregate functions).
- Inverse distribution functions.
- Queries that run functions that are defined with the `ON COORDINATOR` or `ON ALL SEGMENTS` attribute.
- Queries that contain UNICODE characters in metadata names, such as table names, and the characters are not compatible with the host system locale.
- `SELECT`, `UPDATE`, and `DELETE` commands where a table name is qualified by the `ONLY` keyword.
- Per-column collation. GPORCA supports collation only when all columns in the query use the same collation. If columns in the query use different collations, then WarehousePG uses the Postgres-based planner.
- DML and `COPY ... FROM` operations on foreign tables.
- Unsupported index-related features include:
  - Index scan on AO tables
  - Partial dynamic index scan
  - Partial indexes
  - Forward and backward dynamic index and dynamic index-only scans on partitioned tables
  - Indexed expressions (an index defined as an expression based on one or more columns of the table)
  - Combined indexes

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Performance Regressions

The following features are known performance regressions that occur with GPORCA enabled:

- Short running queries - For GPORCA, short running queries might encounter additional overhead due to GPORCA enhancements for determining an optimal query execution plan.
- ANALYZE - For GPORCA, the ANALYZE command generates root partition statistics for partitioned tables. For the Postgres-based planner, these statistics are not generated.
- DML operations - For GPORCA, DML enhancements including the support of updates on partition and distribution keys might require additional overhead.

Also, enhanced functionality of the features from previous versions could result in additional time required when GPORCA runs SQL statements with the features.

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4.6.2.8 Determining the Query Optimizer that is Used

When GPORCA is enabled (the default), you can determine if WarehousePG is using GPORCA or is falling back to the Postgres-based planner.

You can examine the `EXPLAIN` query plan for the query to determine which query optimizer was used by WarehousePG to run the query:

- The optimizer is listed at the end of the query plan. For example, when GPORCA generates the query plan, the query plan ends with:

  ```
  Optimizer: GPORCA
  ```

  When WarehousePG falls back to the Postgres-based planner to generate the plan, the query plan ends with:

  ```
  Optimizer: Postgres-based planner
  ```

- These plan items appear only in the `EXPLAIN` plan output generated by GPORCA. The items are not supported in a Postgres-based planner query plan.

  - Assert operator
  - Sequence operator
  - Dynamic Index Scan
  - Dynamic Seq Scan

- When a query against a partitioned table is generated by GPORCA, the `EXPLAIN` plan displays only the number of partitions that are being eliminated is listed. The scanned partitions are not shown. The `EXPLAIN` plan generated by the Postgres-based planner lists the scanned partitions.

The log file contains messages that indicate which query optimizer was used. If WarehousePG falls back to the Postgres-based planner, a message with `NOTICE` information is added to the log file that indicates the unsupported feature. Also, the label `Planner produced plan:` appears before the query in the query execution log message when WarehousePG falls back to the Postgres optimizer.

> **Note** You can configure WarehousePG to display log messages on the psql command line by setting the WarehousePG server configuration parameter `client_min_messages` to `LOG`. See the *WarehousePG Reference Guide* for information about the parameter.

Parent topic: About GPORCA

Examples

This example shows the differences for a query that is run against partitioned tables when GPORCA is enabled.

This `CREATE TABLE` statement creates a table with single level partitions:

```
CREATE TABLE sales (trans_id int, date date,
    amount decimal(9,2), region text)
   DISTRIBUTED BY (trans_id)
   PARTITION BY RANGE (date)
      (START (date '20160101')
       INCLUSIVE END (date '20170101')
       EXCLUSIVE EVERY (INTERVAL '1 month'),
   DEFAULT PARTITION outlying_dates );
```

This query against the table is supported by GPORCA and does not generate errors in the log file:

```
select * from sales ;
```

The `EXPLAIN` plan output lists only the number of selected partitions.

```
 ->  Partition Selector for sales (dynamic scan id: 1)  (cost=10.00..100.00 rows=50 width=4)
       Partitions selected:  13 (out of 13)
```

If a query against a partitioned table is not supported by GPORCA. WarehousePG falls back to the Postgres-based planner. The `EXPLAIN` plan generated by the Postgres-based planner lists the selected partitions. This example shows a part of the explain plan that lists some selected partitions.

```
 ->  Append  (cost=0.00..0.00 rows=26 width=53)
     ->  Seq Scan on sales2_1_prt_7_2_prt_usa sales2  (cost=0.00..0.00 rows=1 width=53)
     ->  Seq Scan on sales2_1_prt_7_2_prt_asia sales2  (cost=0.00..0.00 rows=1 width=53)
     ...
```

This example shows the log output when the WarehousePG falls back to the Postgres-based planner from GPORCA.

When this query is run, WarehousePG falls back to the Postgres-based planner.

```
explain select * from pg_class;
```

A message is added to the log file. The message contains this `NOTICE` information that indicates the reason GPORCA did not run the query:

```
NOTICE,""Falling back to Postgres-based planner because GPORCA does not support the following feature: Queries on coordinator-only tables"
```

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4.6.3 Defining Queries

WarehousePG is based on the PostgreSQL implementation of the SQL standard.

This topic describes how to construct SQL queries in WarehousePG.

- SQL Lexicon
- SQL Value Expressions

Parent topic: SQL: Querying Data

SQL Lexicon

SQL is a standard language for accessing databases. The language consists of elements that enable data storage, retrieval, analysis, viewing, manipulation, and so on. You use SQL commands to construct queries and commands that the WarehousePG engine understands. SQL queries consist of a sequence of commands. Commands consist of a sequence of valid tokens in correct syntax order, terminated by a semicolon (`;`).

For more information about SQL commands, see SQL Command Reference.

WarehousePG uses PostgreSQL's structure and syntax, with some exceptions. For more information about SQL rules and concepts in PostgreSQL, see "SQL Syntax" in the PostgreSQL documentation.

SQL Value Expressions

SQL value expressions consist of one or more values, symbols, operators, SQL functions, and data. The expressions compare data or perform calculations and return a value as the result. Calculations include logical, arithmetic, and set operations.

The following are value expressions:

- An aggregate expression
- An array constructor
- A column reference
- A constant or literal value
- A correlated subquery
- A field selection expression
- A function call
- A new column value in an `INSERT` or `UPDATE`
- An operator invocation column reference
- A positional parameter reference, in the body of a function definition or prepared statement
- A row constructor
- A scalar subquery
- A search condition in a `WHERE` clause
- A target list of a `SELECT` command
- A type cast
- A value expression in parentheses, useful to group sub-expressions and override precedence
- A window expression

SQL constructs such as functions and operators are expressions but do not follow any general syntax rules. For more information about these constructs, see Using Functions and Operators.

Column References

A column reference has the form:

```
<correlation>.<columnname>
```

Here, `<correlation>` is the name of a table (possibly qualified with a schema name) or an alias for a table defined with a `FROM` clause or one of the keywords `NEW` or `OLD`. `NEW` and `OLD` can appear only in rewrite rules, but you can use other correlation names in any SQL statement. If the column name is unique across all tables in the query, you can omit the `<correlation>` part of the column reference.

Positional Parameters

Positional parameters are arguments to SQL statements or functions that you reference by their positions in a series of arguments. For example, `$1` refers to the first argument, `$2` to the second argument, and so on. The values of positional parameters are set from arguments external to the SQL statement or supplied when SQL functions are invoked. Some client libraries support specifying data values separately from the SQL command, in which case parameters refer to the out-of-line data values. A parameter reference has the form:

```
$number
```

For example:

```
CREATE FUNCTION dept(text) RETURNS dept
    AS $$ SELECT * FROM dept WHERE name = $1 $$
    LANGUAGE SQL;
```

Here, the `$1` references the value of the first function argument whenever the function is invoked.

Subscripts

If an expression yields a value of an array type, you can extract a specific element of the array value as follows:

```
<expression>[<subscript>]
```

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You can extract multiple adjacent elements, called an array slice, as follows (including the brackets):

```
<expression>[<lower_subscript>:<upper_subscript>]
```

Each subscript is an expression and yields an integer value.

Array expressions usually must be in parentheses, but you can omit the parentheses when the expression to be subscripted is a column reference or positional parameter. You can concatenate multiple subscripts when the original array is multidimensional. For example (including the parentheses):

```
mytable.arraycolumn[4]
```

```
mytable.two_d_column[17][34]
```

```
$1[10:42]
```

```
(arrayfunction(a,b))[42]
```

Field Selection

If an expression yields a value of a composite type (row type), you can extract a specific field of the row as follows:

```
<expression>.<fieldname>
```

The row expression usually must be in parentheses, but you can omit these parentheses when the expression to be selected from is a table reference or positional parameter. For example:

```
mytable.mycolumn
```

```
$1.somecolumn
```

```
(rowfunction(a,b)).col3
```

A qualified column reference is a special case of field selection syntax.

Operator Invocations

Operator invocations have the following possible syntaxes:

```
<expression operator expression>(binary infix operator)
```

```
<operator expression>(unary prefix operator)
```

```
<expression operator>(unary postfix operator)
```

Where `operator` is an operator token, one of the key words `AND`, `OR`, or `NOT`, or qualified operator name in the form:

```
OPERATOR(<schema>.<operatorname>)
```

Available operators and whether they are unary or binary depends on the operators that the system or user defines. For more information about built-in operators, see Built-in Functions and Operators.

Function Calls

The syntax for a function call is the name of a function (possibly qualified with a schema name), followed by its argument list enclosed in parentheses:

```
function ([expression [, expression ... ]])
```

For example, the following function call computes the square root of 2:

```
sqrt(2)
```

See Summary of Built-in Functions for lists of the built-in functions by category. You can add custom functions, too.

Aggregate Expressions

An aggregate expression applies an aggregate function across the rows that a query selects. An aggregate function performs a calculation on a set of values and returns a single value, such as the sum or average of the set of values. The syntax of an aggregate expression is one of the following:

- `aggregate_name(expression [ , ... ] ) [ FILTER ( WHERE filter_clause ) ]` — operates across all input rows for which the expected result value is non-null. `ALL` is the default.
- `aggregate_name(ALL expression [ , ... ] ) [ FILTER ( WHERE filter_clause ) ]` — operates identically to the first form because `ALL` is the default.
- `aggregate_name(DISTINCT expression [ , ... ] ) [ FILTER ( WHERE filter_clause ) ]` — operates across all distinct non-null values of input rows.
- `aggregate_name(*) [ FILTER ( WHERE filter_clause ) ]` — operates on all rows with values both null and non-null. Generally, this form is most useful for the `count(*)` aggregate function.

Where `aggregate_name` is a previously defined aggregate (possibly schema-qualified) and `expression` is any value expression that does not contain an aggregate expression.

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For example, `count(*)` yields the total number of input rows, `count(f1)` yields the number of input rows in which `f1` is non-null, and `count(distinct f1)` yields the number of distinct non-null values of `f1`.

If `FILTER` is specified, then only the input rows for which the `filter_clause` evaluates to true are fed to the aggregate function; other rows are discarded. For example:

```
SELECT
    count(*) AS unfiltered,
    count(*) FILTER (WHERE i < 5) AS filtered
FROM generate_series(1,10) AS s(i);
 unfiltered | filtered
------------+----------
         10 |        4
(1 row)
```

For predefined aggregate functions, see Built-in Functions and Operators. You can also add custom aggregate functions.

WarehousePG provides the `MEDIAN` aggregate function, which returns the fiftieth percentile of the `PERCENTILE_CONT` result and special aggregate expressions for inverse distribution functions as follows:

```
PERCENTILE_CONT(<percentage>) WITHIN GROUP (ORDER BY <expression>)
```

```
PERCENTILE_DISC(<percentage>) WITHIN GROUP (ORDER BY <expression>)
```

Currently you can use only these two expressions with the keyword `WITHIN GROUP`.

Limitations of Aggregate Expressions

The following are current limitations of the aggregate expressions:

- WarehousePG does not support the following keywords: `ALL`, `DISTINCT`, and `OVER`. See Table 5 for more details.
- An aggregate expression can appear only in the result list or `HAVING` clause of a `SELECT` command. It is forbidden in other clauses, such as `WHERE`, because those clauses are logically evaluated before the results of aggregates form. This restriction applies to the query level to which the aggregate belongs.
- When an aggregate expression appears in a subquery, the aggregate is normally evaluated over the rows of the subquery. If the aggregate's arguments (and `filter_clause` if any) contain only outer-level variables, the aggregate belongs to the nearest such outer level and evaluates over the rows of that query. The aggregate expression as a whole is then an outer reference for the subquery in which it appears, and the aggregate expression acts as a constant over any one evaluation of that subquery. The restriction about appearing only in the result list or `HAVING` clause applies with respect to the query level at which the aggregate appears. See Scalar Subqueries and Table 3.
- WarehousePG does not support specifying an aggregate function as an argument to another aggregate function.
- WarehousePG does not support specifying a window function as an argument to an aggregate function.

Window Expressions

Window expressions allow application developers to more easily compose complex online analytical processing (OLAP) queries using standard SQL commands. For example, with window expressions, users can calculate moving averages or sums over various intervals, reset aggregations and ranks as selected column values change, and express complex ratios in simple terms.

A window expression represents the application of a `<window function>` to a `<window frame>`, which is defined with an `OVER()` clause. This is comparable to the type of calculation that can be done with an aggregate function and a `GROUP BY` clause. Unlike aggregate functions, which return a single result value for each group of rows, window functions return a result value for every row, but that value is calculated with respect to the set of rows in the window frame to which the row belongs. The `OVER()` clause allows dividing the rows into *partitions* and then further restricting the window frame by specifying which rows preceding or following the current row within its partition to include in the calculation.

WarehousePG does not support specifying a window function as an argument to another window function.

The syntax of a window expression is:

```
<window_function> ( [<expression> [, ...]] ) [ FILTER ( WHERE <filter_clause> ) ] OVER ( <window_specification> )
```

Where `<window_function>` is one of the functions listed in Table 4 or a user-defined window function, `<expression>` is any value expression that does not contain a window expression, and `<window_specification>` is:

```
[<window_name>]
[PARTITION BY <expression> [, ...]]
[[ORDER BY <expression> [ASC | DESC | USING operator] [NULLS {FIRST | LAST}] [, ...]
[ <frame_clause> ]
```

The optional `<frame_clause>` can be one of the following:

```
{ RANGE | ROWS | GROUPS } <frame_start> [ <frame_exclusion> ]
{ RANGE | ROWS | GROUPS } BETWEEN <frame_start> AND <frame_end> [ <frame_exclusion> ]
```

Where `<frame_start>` and `<frame_end>` can be one of the following:

```
UNBOUNDED PRECEDING
<offset> PRECEDING
CURRENT ROW
<offset> FOLLOWING
UNBOUNDED FOLLOWING
```

and `<frame_exclusion>` can be one of the following:

```
EXCLUDE CURRENT ROW
EXCLUDE GROUP
EXCLUDE TIES
EXCLUDE NO OTHERS
```

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A window expression can appear only in the select list of a `SELECT` command. For example:

```
SELECT count(*) OVER(PARTITION BY customer_id), * FROM sales;
```

If `FILTER` is specified, then only the input rows for which the `<filter_clause>` evaluates to true are fed to the window function; other rows are discarded. In a window expression, a `FILTER` clause can be used only with a `<window_function>` that is an aggregate function.

In a window expression, the expression must contain an `OVER` clause. The `OVER` clause specifies the window frame—the rows to be processed by the window function. This syntactically distinguishes the function from a regular or aggregate function.

In a window aggregate function that is used in a window expression, WarehousePG does not support a `DISTINCT` clause with multiple input expressions.

A window specification has the following characteristics:

- The `PARTITION BY` clause defines the window partitions to which the window function is applied. If omitted, the entire result set is treated as one partition.
- The `ORDER BY` clause defines the expression(s) for sorting rows within a window partition. The `ORDER BY` clause of a window specification is separate and distinct from the `ORDER BY` clause of a regular query expression. The `ORDER BY` clause is required for the window functions that calculate rankings, as it identifies the measure(s) for the ranking values. For OLAP aggregations, the `ORDER BY` clause is required to use window frames (the `ROWS`, `RANGE` or `GROUPS` clause).

> **Note** Columns of data types without a coherent ordering, such as `time`, are not good candidates for use in the `ORDER BY` clause of a window specification. `Time`, with or without a specified time zone, lacks a coherent ordering because addition and subtraction do not have the expected effects. For example, the following is not generally true: `x::time < x::time + '2 hour'::interval`

- The `<frame_clause>` specifies the set of rows constituting the `<window frame>`, which is a subset of the current partition, for those window functions that act on the frame instead of the whole partition. The set of rows in the frame can vary depending on which row is the current row. The frame can be specified in `RANGE`, `ROWS` or `GROUPS` mode; in each case, it runs from the `<frame_start>` to the `<frame_end>`. If `<frame_end>` is omitted, the end defaults to `CURRENT ROW`.
- A `<frame_start>` of `UNBOUNDED PRECEDING` means that the frame starts with the first row of the partition, and similarly a `<frame_end>` of `UNBOUNDED FOLLOWING` means that the frame ends with the last row of the partition.
- In `RANGE` or `GROUPS` mode, a `<frame_start>` of `CURRENT ROW` means the frame starts with the current row's first peer row (a row that the window's `ORDER BY` clause sorts as equivalent to the current row), while a `<frame_end>` of `CURRENT ROW` means the frame ends with the current row's last peer row. In `ROWS` mode, `CURRENT ROW` simply means the current row.
- In the `<offset> PRECEDING` and `<offset> FOLLOWING` frame options, the `<offset>` must be an expression not containing any variables, aggregate functions, or window functions. The meaning of the `<offset>` depends on the frame mode:
    - In `ROWS` mode, the `<offset>` must yield a non-null, non-negative integer, and the option means that the frame starts or ends the specified number of rows before or after the current row.
    - In `GROUPS` mode, the `<offset>` again must yield a non-null, non-negative integer, and the option means that the frame starts or ends the specified number of peer groups before or after the current row's peer group, where a peer group is a set of rows that are equivalent in the `ORDER BY` ordering. (There must be an `ORDER BY` clause in the window definition to use `GROUPS` mode).
    - In `RANGE` mode, these options require that the `ORDER BY` clause specifies exactly one column. The `<offset>` specifies the maximum difference between the value of that column in the current row and its value in preceding or following rows of the frame. The data type of the `<offset>` expression varies depending on the data type of the ordering column. For numeric ordering columns it is typically of the same type as the ordering column, but for datetime ordering columns it is an `interval`. For example, if the ordering column is of type `date` or `timestamp`, one could write `RANGE BETWEEN '1 day' PRECEDING AND '10 days' FOLLOWING`. The `<offset>` is still required to be non-null and non-negative, though the meaning of "non-negative" depends on its data type.

      In any case, the distance to the end of the frame is limited by the distance to the end of the partition, so that for rows near the partition ends the frame might contain fewer rows than elsewhere.
- Notice that in both `ROWS` and `GROUPS` mode, `0 PRECEDING` and `0 FOLLOWING` are equivalent to `CURRENT ROW`. This normally holds in `RANGE` mode as well, for an appropriate data-type-specific meaning of "zero".
- The `<frame_exclusion>` option allows rows around the current row to be excluded from the frame, even if they would be included according to the frame start and frame end options. `EXCLUDE CURRENT ROW` excludes the current row from the frame. `EXCLUDE GROUP` excludes the current row and its ordering peers from the frame. `EXCLUDE TIES` excludes any peers of the current row from the frame, but not the current row itself. `EXCLUDE NO OTHERS` simply specifies explicitly the default behavior of not excluding the current row or its peers.
- The default framing option is `RANGE UNBOUNDED PRECEDING`, which is the same as `RANGE BETWEEN UNBOUNDED PRECEDING AND CURRENT ROW`. With `ORDER BY`, this sets the frame to be all rows from the partition start up through the current row's last `ORDER BY` peer. Without `ORDER BY`, this means all rows of the partition are included in the window frame, since all rows become peers of the current row.
- Restrictions are that `<frame_start>` cannot be `UNBOUNDED FOLLOWING`, `<frame_end>` cannot be `UNBOUNDED PRECEDING`, and the `<frame_end>` choice cannot appear earlier in the above list than the `<frame_start>` choice. for example `RANGE BETWEEN CURRENT ROW AND value PRECEDING` is not allowed.

Window Examples

The following examples demonstrate using window functions with partitions and window frames.

Example 1 – Aggregate Window Function Over a Partition

The `PARTITION BY` list in the `OVER` clause divides the rows into groups, or partitions, that have the same values as the specified expressions.

This example compares employees' salaries with the average salaries for their departments:

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```
SELECT depname, empno, salary, avg(salary) OVER(PARTITION BY depname)
FROM empsalary;
  depname  | empno | salary |          avg
-----------+-------+--------+-----------------------
 develop   |     9 |   4500 | 5020.0000000000000000
 develop   |    10 |   5200 | 5020.0000000000000000
 develop   |    11 |   5200 | 5020.0000000000000000
 develop   |     7 |   4200 | 5020.0000000000000000
 develop   |     8 |   6000 | 5020.0000000000000000
 personnel |     5 |   3500 | 3700.0000000000000000
 personnel |     2 |   3900 | 3700.0000000000000000
 sales     |     1 |   5000 | 4866.6666666666666667
 sales     |     3 |   4800 | 4866.6666666666666667
 sales     |     4 |   4800 | 4866.6666666666666667
(10 rows)
```

The first three output columns come from the table `empsalary`, and there is one output row for each row in the table. The fourth column is the average calculated on all rows that have the same `depname` value as the current row. Rows that share the same `depname` value constitute a partition, and there are three partitions in this example. The `avg` function is the same as the regular `avg` aggregate function, but the `OVER` clause causes it to be applied as a window function.

You can also put the window specification in a `WINDOW` clause and reference it in the select list. This example is equivalent to the previous query:

```
SELECT depname, empno, salary, avg(salary) OVER(mywindow)
FROM empsalary
WINDOW mywindow AS (PARTITION BY depname);
```

Defining a named window is useful when the select list has multiple window functions using the same window specification.

Example 2 – Ranking Window Function With an ORDER BY Clause

An `ORDER BY` clause within the `OVER` clause controls the order in which rows are processed by window functions. The `ORDER BY` list for the window function does not have to match the output order of the query. This example uses the `rank()` window function to rank employees' salaries within their departments:

```
SELECT depname, empno, salary,
    rank() OVER (PARTITION BY depname ORDER BY salary DESC)
FROM empsalary;
  depname  | empno | salary | rank
-----------+-------+--------+------
 develop   |     8 |   6000 |    1
 develop   |    11 |   5200 |    2
 develop   |    10 |   5200 |    2
 develop   |     9 |   4500 |    4
 develop   |     7 |   4200 |    5
 personnel |     2 |   3900 |    1
 personnel |     5 |   3500 |    2
 sales     |     1 |   5000 |    1
 sales     |     4 |   4800 |    2
 sales     |     3 |   4800 |    2
(10 rows)
```

Example 3 – Aggregate Function over a Row Window Frame

A `RANGE`, `ROWS` or `GROUPS` clause defines the window frame—a set of rows within a partition—that the window function includes in the calculation. `ROWS` specifies a physical set of rows to process, for example all rows from the beginning of the partition to the current row.

This example calculates a running total of employee's salaries by department using the `sum()` function to total rows from the start of the partition to the current row:

```
SELECT depname, empno, salary,
    sum(salary) OVER (PARTITION BY depname ORDER BY salary
        ROWS between UNBOUNDED PRECEDING AND CURRENT ROW)
FROM empsalary ORDER BY depname, sum;
  depname  | empno | salary |  sum
-----------+-------+--------+-------
 develop   |     7 |   4200 |  4200
 develop   |     9 |   4500 |  8700
 develop   |    11 |   5200 | 13900
 develop   |    10 |   5200 | 19100
 develop   |     8 |   6000 | 25100
 personnel |     5 |   3500 |  3500
 personnel |     2 |   3900 |  7400
 sales     |     4 |   4800 |  4800
 sales     |     3 |   4800 |  9600
 sales     |     1 |   5000 | 14600
(10 rows)
```

Example 4 – Aggregate Function for a Range or Groups Window Frame

`RANGE` and `GROUPS` modes specify logical values based on values of the `ORDER BY` expression in the `OVER` clause. This example demonstrates the difference between `ROWS` and `RANGE` or `GROUPS`. The frame contains all rows with salary values less than or equal to the current row. Unlike the previous example, for employees with the same salary, the sum is the same and includes the salaries of all of those employees.

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```
SELECT depname, empno, salary,
    sum(salary) OVER (PARTITION BY depname ORDER BY salary
        RANGE between UNBOUNDED PRECEDING AND CURRENT ROW)
FROM empsalary ORDER BY depname, sum;
  depname  | empno | salary |  sum
-----------+-------+--------+-------
 develop   |     7 |   4200 |  4200
 develop   |     9 |   4500 |  8700
 develop   |    11 |   5200 | 19100
 develop   |    10 |   5200 | 19100
 develop   |     8 |   6000 | 25100
 personnel |     5 |   3500 |  3500
 personnel |     2 |   3900 |  7400
 sales     |     4 |   4800 |  9600
 sales     |     3 |   4800 |  9600
 sales     |     1 |   5000 | 14600
(10 rows)
```

In this example, since the `<frame_start>` and `<frame_end>` are not using an `<offset>`, `RANGE` and `GROUPS` mode provide identical results:

```
SELECT depname, empno, salary,
    sum(salary) OVER (PARTITION BY depname ORDER BY salary
        GROUPS between UNBOUNDED PRECEDING AND CURRENT ROW)
FROM empsalary ORDER BY depname, sum;
  depname  | empno | salary |  sum
-----------+-------+--------+-------
 develop   |     7 |   4200 |  4200
 develop   |     9 |   4500 |  8700
 develop   |    11 |   5200 | 19100
 develop   |    10 |   5200 | 19100
 develop   |     8 |   6000 | 25100
 personnel |     5 |   3500 |  3500
 personnel |     2 |   3900 |  7400
 sales     |     4 |   4800 |  9600
 sales     |     3 |   4800 |  9600
 sales     |     1 |   5000 | 14600
(10 rows)
```

Example 5 – Aggregate Function for a Range and a Groups Window Frame

This example demonstrates the difference between `RANGE` and `GROUPS`. The table `sales` lists the sales a company's two shops during a period of four days.

When using `GROUPS` mode, the value of `<offset>` indicates the number of peer groups before the current row's peer group. The different peer groups are set by the `ORDER BY` clause, in this case the date. Since the query does not specify a value for `<frame_end>`, the end defaults to `CURRENT ROW`.

```
SELECT date, shop, total, sum(total) OVER (PARTITION BY shop ORDER BY date asc GROUPS 2 PRECEDING)
FROM sales ORDER BY shop, date;
    date    |  shop  |  total  |   sum
------------+--------+---------+----------
 2022-01-07 | Shop 1 | 3000.00 |  3000.00
 2022-01-08 | Shop 1 | 1000.00 |  4000.00
 2022-01-09 | Shop 1 | 5000.00 | 11000.00
 2022-01-09 | Shop 1 | 2000.00 | 11000.00
 2022-01-07 | Shop 2 | 4000.00 | 10000.00
 2022-01-07 | Shop 2 | 6000.00 | 10000.00
 2022-01-09 | Shop 2 | 7000.00 | 21000.00
 2022-01-09 | Shop 2 | 4000.00 | 21000.00
 2022-01-10 | Shop 2 | 2000.00 | 23000.00
(9 rows)
```

In order to get the equivalent result when using the `RANGE` mode, the `<frame_clause>` must specify an `<offset>` using the same data type as the ordering column, in this case `date`. Using the numberic value `2` will return an error.

```
SELECT date, shop, total, sum(total) OVER (PARTITION BY shop ORDER BY date asc RANGE '2 days' PRECEDING)
FROM sales ORDER BY shop, date;
    date    |  shop  |  total  |   sum
------------+--------+---------+----------
 2022-01-07 | Shop 1 | 3000.00 |  3000.00
 2022-01-08 | Shop 1 | 1000.00 |  4000.00
 2022-01-09 | Shop 1 | 5000.00 | 11000.00
 2022-01-09 | Shop 1 | 2000.00 | 11000.00
 2022-01-07 | Shop 2 | 4000.00 | 10000.00
 2022-01-07 | Shop 2 | 6000.00 | 10000.00
 2022-01-09 | Shop 2 | 7000.00 | 21000.00
 2022-01-09 | Shop 2 | 4000.00 | 21000.00
 2022-01-10 | Shop 2 | 2000.00 | 13000.00
(9 rows)
```

Note that the above outputs differ in the last row because `RANGE` mode uses the entries from the previous two days and there is no entry for `2022-01-08` for Shop 2, but `GROUPS` mode uses the previous two peer groups, which are `2022-01-07` and `2022-01-09`.

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Type Casts

A type cast specifies a conversion from one data type to another. A cast applied to a value expression of a known type is a run-time type conversion. The cast succeeds only if a suitable type conversion is defined. This differs from the use of casts with constants. A cast applied to a string literal represents the initial assignment of a type to a literal constant value, so it succeeds for any type if the contents of the string literal are acceptable input syntax for the data type.

WarehousePG supports three types of casts applied to a value expression:

- *Explicit cast* - WarehousePG applies a cast when you explicitly specify a cast between two data types. WarehousePG accepts two equivalent syntaxes for explicit type casts:

  ```
  CAST ( expression AS type )
  expression::type
  ```

  The `CAST` syntax conforms to SQL; the syntax using `::` is historical PostgreSQL usage.

- *Assignment cast* - WarehousePG implicitly invokes a cast in assignment contexts, when assigning a value to a column of the target data type. For example, a`CREATE CAST` command with the `AS ASSIGNMENT` clause creates a cast that is applied implicitly in the assignment context. This example assignment cast assumes that `tbl1.f1` is a column of type `text`. The `INSERT` command is allowed because the value is implicitly cast from the `integer` to `text` type.

  ```
  INSERT INTO tbl1 (f1) VALUES (42);
  ```

- *Implicit cast* - WarehousePG implicitly invokes a cast in assignment or expression contexts. For example, a `CREATE CAST` command with the `AS IMPLICIT` clause creates an implicit cast, a cast that is applied implicitly in both the assignment and expression context. This example implicit cast assumes that `tbl1.c1` is a column of type `int`. For the calculation in the predicate, the value of `c1` is implicitly cast from `int` to a `decimal` type.

  ```
  SELECT * FROM tbl1 WHERE tbl1.c2 = (4.3 + tbl1.c1) ;
  ```

You can usually omit an explicit type cast if there is no ambiguity about the type a value expression must produce (for example, when it is assigned to a table column); the system automatically applies a type cast. WarehousePG implicitly applies casts only to casts defined with a cast context of assignment or explicit in the system catalogs. Other casts must be invoked with explicit casting syntax to prevent unexpected conversions from being applied without the user's knowledge.

You can display cast information with the `psql` meta-command `\dC`. Cast information is stored in the catalog table `pg_cast`, and type information is stored in the catalog table `pg_type`.

Scalar Subqueries

A scalar subquery is a `SELECT` query in parentheses that returns exactly one row with one column. Do not use a `SELECT` query that returns multiple rows or columns as a scalar subquery. The query runs and uses the returned value in the surrounding value expression. A correlated scalar subquery contains references to the outer query block.

Correlated Subqueries

A correlated subquery (CSQ) is a `SELECT` query with a `WHERE` clause or target list that contains references to the parent outer clause. CSQs efficiently express results in terms of results of another query. WarehousePG supports correlated subqueries that provide compatibility with many existing applications. A CSQ is a scalar or table subquery, depending on whether it returns one or multiple rows. WarehousePG does not support correlated subqueries with skip-level correlations.

Correlated Subquery Examples

Example 1 – Scalar correlated subquery

```
SELECT * FROM t1 WHERE t1.x
           > (SELECT MAX(t2.x) FROM t2 WHERE t2.y = t1.y);
```

Example 2 – Correlated EXISTS subquery

```
SELECT * FROM t1 WHERE
EXISTS (SELECT 1 FROM t2 WHERE t2.x = t1.x);
```

WarehousePG uses one of the following methods to run CSQs:

- Unnest the CSQ into join operations – This method is most efficient, and it is how WarehousePG runs most CSQs, including queries from the TPC-H benchmark.
- Run the CSQ on every row of the outer query – This method is relatively inefficient, and it is how WarehousePG runs queries that contain CSQs in the `SELECT` list or are connected by `OR` conditions.

The following examples illustrate how to rewrite some of these types of queries to improve performance.

Example 3 - CSQ in the Select List

Original Query

```
SELECT T1.a,
      (SELECT COUNT(DISTINCT T2.z) FROM t2 WHERE t1.x = t2.y) dt2
FROM t1;
```

Rewrite this query to perform an inner join with `t1` first and then perform a left join with `t1` again. The rewrite applies for only an equijoin in the correlated condition.

Rewritten Query

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```
SELECT t1.a, dt2 FROM t1
       LEFT JOIN
        (SELECT t2.y AS csq_y, COUNT(DISTINCT t2.z) AS dt2
              FROM t1, t2 WHERE t1.x = t2.y
              GROUP BY t1.x)
       ON (t1.x = csq_y);
```

Example 4 - CSQs connected by OR Clauses

Original Query

```
SELECT * FROM t1
WHERE
x > (SELECT COUNT(*) FROM t2 WHERE t1.x = t2.x)
OR x < (SELECT COUNT(*) FROM t3 WHERE t1.y = t3.y)
```

Rewrite this query to separate it into two parts with a union on the `OR` conditions.

Rewritten Query

```
SELECT * FROM t1
WHERE x > (SELECT count(*) FROM t2 WHERE t1.x = t2.x)
UNION
SELECT * FROM t1
WHERE x < (SELECT count(*) FROM t3 WHERE t1.y = t3.y)
```

To view the query plan, use `EXPLAIN SELECT` or `EXPLAIN ANALYZE SELECT`. Subplan nodes in the query plan indicate that the query will run on every row of the outer query, and the query is a candidate for rewriting. For more information about these statements, see Query Profiling.

Array Constructors

An array constructor is an expression that builds an array value from values for its member elements. A simple array constructor consists of the key word `ARRAY`, a left square bracket `[`, one or more expressions separated by commas for the array element values, and a right square bracket `]`. For example,

```
SELECT ARRAY[1,2,3+4];
  array
---------
 {1,2,7}
```

The array element type is the common type of its member expressions, determined using the same rules as for `UNION` or `CASE` constructs.

You can build multidimensional array values by nesting array constructors. In the inner constructors, you can omit the keyword `ARRAY`. For example, the following two `SELECT` statements produce the same result:

```
SELECT ARRAY[ARRAY[1,2], ARRAY[3,4]];
SELECT ARRAY[[1,2],[3,4]];
     array
---------------
 {{1,2},{3,4}}
```

Since multidimensional arrays must be rectangular, inner constructors at the same level must produce sub-arrays of identical dimensions.

Multidimensional array constructor elements are not limited to a sub-`ARRAY` construct; they are anything that produces an array of the proper kind. For example:

```
CREATE TABLE arr(f1 int[], f2 int[]);
INSERT INTO arr VALUES (ARRAY[[1,2],[3,4]],
ARRAY[[5,6],[7,8]]);
SELECT ARRAY[f1, f2, '{{9,10},{11,12}}'::int[]] FROM arr;
                     array
-----------------------------------------------
 {{{1,2},{3,4}},{{5,6},{7,8}},{{9,10},{11,12}}}
```

You can construct an array from the results of a subquery. Write the array constructor with the keyword `ARRAY` followed by a subquery in parentheses. For example:

```
SELECT ARRAY(SELECT oid FROM pg_proc WHERE proname LIKE 'bytea%');
                          ?column?
------------------------------------------------------------
 {2011,1954,1948,1952,1951,1244,1950,2005,1949,1953,2006,31}
```

The subquery must return a single column. The resulting one-dimensional array has an element for each row in the subquery result, with an element type matching that of the subquery's output column. The subscripts of an array value built with `ARRAY` always begin with `1`.

Row Constructors

A row constructor is an expression that builds a row value (also called a composite value) from values for its member fields. For example,

```
SELECT ROW(1,2.5,'this is a test');
```

Row constructors have the syntax `rowvalue.*`, which expands to a list of the elements of the row value, as when you use the syntax `.*` at the top level of a `SELECT` list. For example, if table `t` has columns `f1` and `f2`, the following queries are the same:

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```
SELECT ROW(t.*, 42) FROM t;
SELECT ROW(t.f1, t.f2, 42) FROM t;
```

By default, the value created by a `ROW` expression has an anonymous record type. If necessary, it can be cast to a named composite type — either the row type of a table, or a composite type created with `CREATE TYPE AS`. To avoid ambiguity, you can explicitly cast the value if necessary. For example:

```
CREATE TABLE mytable(f1 int, f2 float, f3 text);
CREATE FUNCTION getf1(mytable) RETURNS int AS 'SELECT $1.f1'
LANGUAGE SQL;
```

In the following query, you do not need to cast the value because there is only one `getf1()` function and therefore no ambiguity:

```
SELECT getf1(ROW(1,2.5,'this is a test'));
 getf1
-------
     1
CREATE TYPE myrowtype AS (f1 int, f2 text, f3 numeric);
CREATE FUNCTION getf1(myrowtype) RETURNS int AS 'SELECT
$1.f1' LANGUAGE SQL;
```

Now we need a cast to indicate which function to call:

```
SELECT getf1(ROW(1,2.5,'this is a test'));
ERROR:  function getf1(record) is not unique
```

```
SELECT getf1(ROW(1,2.5,'this is a test')::mytable);
 getf1
-------
     1
SELECT getf1(CAST(ROW(11,'this is a test',2.5) AS
myrowtype));
 getf1
-------
    11
```

You can use row constructors to build composite values to be stored in a composite-type table column or to be passed to a function that accepts a composite parameter.

Expression Evaluation Rules

The order of evaluation of subexpressions is undefined. The inputs of an operator or function are not necessarily evaluated left-to-right or in any other fixed order.

If you can determine the result of an expression by evaluating only some parts of the expression, then other subexpressions might not be evaluated at all. For example, in the following expression:

```
SELECT true OR somefunc();
```

`somefunc()` would probably not be called at all. The same is true in the following expression:

```
SELECT somefunc() OR true;
```

This is not the same as the left-to-right evaluation order that Boolean operators enforce in some programming languages.

Do not use functions with side effects as part of complex expressions, especially in `WHERE` and `HAVING` clauses, because those clauses are extensively reprocessed when developing an execution plan. Boolean expressions (`AND` / `OR` / `NOT` combinations) in those clauses can be reorganized in any manner that Boolean algebra laws allow.

Use a `CASE` construct to force evaluation order. The following example is an untrustworthy way to avoid division by zero in a `WHERE` clause:

```
SELECT ... WHERE x <> 0 AND y/x > 1.5;
```

The following example shows a trustworthy evaluation order:

```
SELECT ... WHERE CASE WHEN x <> 0 THEN y/x > 1.5 ELSE false
END;
```

This `CASE` construct usage defeats optimization attempts; use it only when necessary.

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4.6.4 WITH Queries (Common Table Expressions)

The `WITH` clause provides a way to write auxiliary statements for use in a larger query. These statements, which are often referred to as Common Table Expressions or CTEs, can be thought of as defining temporary tables that exist just for one query.

> **Note** Limitations when using a `WITH` clause in WarehousePG include:
>
> - For a `SELECT` command that includes a `WITH` clause, the clause can contain at most a single clause that modifies table data (`INSERT`, `UPDATE`, or `DELETE` command).
> - For a data-modifying command (`INSERT`, `UPDATE`, or `DELETE`) that includes a `WITH` clause, the clause can only contain a `SELECT` command; it cannot contain a data-modifying command.

By default, WarehousePG enables the `RECURSIVE` keyword for the `WITH` clause. `RECURSIVE` can be deactivated by setting the server configuration parameter gp_recursive_cte to `false`.

Parent topic: SQL: Querying Data

SELECT in a WITH Clause

One use of CTEs is to break down complicated queries into simpler parts. The examples in this section show the `WITH` clause being used with a `SELECT` command. The example `WITH` clauses can be used the same manner with `INSERT`, `UPDATE`, or `DELETE`.

A `SELECT` command in the `WITH` clause is evaluated only once per execution of the parent query, even if it is referred to more than once by the parent query or sibling `WITH` clauses. Thus, expensive calculations that are needed in multiple places can be placed within a `WITH` clause to avoid redundant work. Another possible application is to prevent unwanted multiple evaluations of functions with side-effects. However, the other side of this coin is that the optimizer is less able to push restrictions from the parent query down into a `WITH` query than an ordinary sub-query. The `WITH` query will generally be evaluated as written, without suppression of rows that the parent query might discard afterwards. However, evaluation might stop early if the references to the query demand only a limited number of rows.

The following example query displays per-product sales totals in only the top sales regions:

```
WITH regional_sales AS (
     SELECT region, SUM(amount) AS total_sales
     FROM orders
     GROUP BY region
  ), top_regions AS (
     SELECT region
     FROM regional_sales
     WHERE total_sales > (SELECT SUM(total_sales)/10 FROM regional_sales)
  )
SELECT region,
    product,
    SUM(quantity) AS product_units,
    SUM(amount) AS product_sales
FROM orders
WHERE region IN (SELECT region FROM top_regions)
GROUP BY region, product;
```

The `WITH` clause defines two auxiliary statements named `regional_sales` and `top_regions`, where the output of `regional_sales` is used in `top_regions` and the output of `top_regions` is used in the primary `SELECT` query. The query could have been written without the `WITH` clause, but would have required two levels of nested sub- `SELECT`s.

When you specify the optional `RECURSIVE` keyword, the `WITH` clause can accomplish operations not otherwise possible in standard SQL. Using `RECURSIVE`, a `WITH` query can refer to its own output. This simple example computes the sum of integers from 1 through 100:

```
WITH RECURSIVE t(n) AS (
    VALUES (1)
  UNION ALL
    SELECT n+1 FROM t WHERE n < 100
)
SELECT sum(n) FROM t;
```

The general form of a recursive `WITH` query always follows the pattern of: a *non-recursive term*, followed by a `UNION` (or `UNION ALL`), and then a *recursive term*, where only the *recursive term* can contain a reference to the query output.

```
<non_recursive_term> UNION [ ALL ] <recursive_term>
```

A recursive `WITH` query that contains a `UNION [ ALL ]` is evaluated as follows:

1. Evaluate the non-recursive term. For `UNION` (but not `UNION ALL`), discard duplicate rows. Include all remaining rows in the result of the recursive query, and also place them in a temporary *working table*.
2. As long as the working table is not empty, repeat these steps:
    1. Evaluate the recursive term, substituting the current contents of the working table for the recursive self-reference. For `UNION` (but not `UNION ALL`), discard duplicate rows and rows that duplicate any previous result row. Include all remaining rows in the result of the recursive query, and also place them in a temporary *intermediate table*.
    2. Replace the contents of the *working table* with the contents of the *intermediate table*, then empty the *intermediate table*.

> **Note** While `RECURSIVE` allows queries to be specified recursively, WarehousePG evaluates such queries iteratively internally.

In the example above, the working table has just a single row in each step, and it takes on the values from 1 through 100 in successive steps. In the 100th step, there is no output because of the `WHERE` clause, and so the query terminates.

Recursive `WITH` queries are typically used to deal with hierarchical or tree-structured data. For example, this query locates all of the direct and indirect sub-parts of a product, given only a table that shows immediate inclusions:

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```
WITH RECURSIVE included_parts(sub_part, part, quantity) AS (
    SELECT sub_part, part, quantity FROM parts WHERE part = 'our_product'
  UNION ALL
    SELECT p.sub_part, p.part, p.quantity * pr.quantity
    FROM included_parts pr, parts p
    WHERE p.part = pr.sub_part
)
SELECT sub_part, SUM(quantity) as total_quantity
FROM included_parts
GROUP BY sub_part;
```

When working with recursive `WITH` queries, you must ensure that the recursive part of the query eventually returns no tuples, or else the query loops indefinitely.

For some queries, using `UNION` instead of `UNION ALL` can ensure that the recursive part of the query eventually returns no tuples by discarding rows that duplicate previous output rows. However, often a cycle does not involve output rows that are complete duplicates: it might be sufficient to check just one or a few fields to see if the same point has been reached before. The standard method for handling such situations is to compute an array of the visited values. For example, consider the following query that searches a table `graph` using a `link` field:

```
WITH RECURSIVE search_graph(id, link, data, depth) AS (
    SELECT g.id, g.link, g.data, 1
    FROM graph g
  UNION ALL
    SELECT g.id, g.link, g.data, sg.depth + 1
    FROM graph g, search_graph sg
    WHERE g.id = sg.link
)
SELECT * FROM search_graph;
```

This query loops if the `link` relationships contain cycles. Because the query requires a `depth` output, changing `UNION ALL` to `UNION` does not eliminate the looping. Instead the query needs to recognize whether it has reached the same row again while following a particular path of links. This modified query adds two columns, `path` and `cycle`, to the loop-prone query:

```
WITH RECURSIVE search_graph(id, link, data, depth, path, cycle) AS (
    SELECT g.id, g.link, g.data, 1,
      ARRAY[g.id],
      false
    FROM graph g
  UNION ALL
    SELECT g.id, g.link, g.data, sg.depth + 1,
      path || g.id,
      g.id = ANY(path)
    FROM graph g, search_graph sg
    WHERE g.id = sg.link AND NOT cycle
)
SELECT * FROM search_graph;
```

Aside from detecting cycles, the array value is useful in its own right since it represents the "path" taken to reach any particular row.

In the general case where more than one field needs to be checked to recognize a cycle, use an array of rows. For example, if we needed to compare fields `f1` and `f2`:

```
WITH RECURSIVE search_graph(id, link, data, depth, path, cycle) AS (
    SELECT g.id, g.link, g.data, 1,
      ARRAY[ROW(g.f1, g.f2)],
      false
    FROM graph g
  UNION ALL
    SELECT g.id, g.link, g.data, sg.depth + 1,
      path || ROW(g.f1, g.f2),
      ROW(g.f1, g.f2) = ANY(path)
    FROM graph g, search_graph sg
    WHERE g.id = sg.link AND NOT cycle
)
SELECT * FROM search_graph;
```

Tip: Omit the `ROW()` syntax in the case where only one field must be checked to recognize a cycle. This uses a simple array rather than a composite-type array, gaining efficiency.

Tip: The recursive query evaluation algorithm produces its output in breadth-first search order. You can display the results in depth-first search order by making the outer query `ORDER BY` a "path" column constructed in this way.

A helpful technique for testing a query when you are not certain if it might loop indefinitely is to place a `LIMIT` in the parent query. For example, the following query would loop forever without the `LIMIT` clause:

```
WITH RECURSIVE t(n) AS (
    SELECT 1
  UNION ALL
    SELECT n+1 FROM t
)
SELECT n FROM t LIMIT 100;
```

This technique works because WarehousePG evaluates only as many rows of a `WITH` query as are actually fetched by the parent query. *Using this technique in production environments is not recommended*, because other systems might work differently. Also, the technique might not work if the outer query sorts the recursive `WITH` results or joins the results to another table, because in such cases the outer query will usually try to fetch all of the `WITH` query's output anyway.

A useful property of `WITH` queries is that they are normally evaluated only once per execution of the parent query, even if they are referred to more than once by the parent query or sibling `WITH` queries. Thus, expensive calculations that are needed in multiple places can be placed within a `WITH` query to avoid redundant work. Another possible application is to prevent unwanted multiple evaluations of functions with side-effects. However, the other side of this coin is that the optimizer is not able to push restrictions from the parent query down into a multiply-referenced `WITH` query, since that might affect all uses of the `WITH` query's output when it should affect only one. WarehousePG evalues the multiply-referenced `WITH` query as written, without suppression of rows that the parent query might discard afterwards. (But, as mentioned above, evaluation might stop early if the reference(s) to the query demand only a limited number of rows.)

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If a `WITH` query is non-recursive and side-effect-free (that is, it is a `SELECT` containing no volatile functions) then it can be folded into the parent query, allowing joint optimization of the two query levels. By default, this happens if the parent query references the `WITH` query just once, but not if it references the `WITH` query more than once. You can override that decision by specifying `MATERIALIZED` to force separate calculation of the `WITH` query, or by specifying `NOT MATERIALIZED` to force it to be merged into the parent query. The latter choice risks duplicate computation of the `WITH` query, but it can still give a net savings if each usage of the `WITH` query needs only a small part of the `WITH` query's full output.

A simple example of these rules follows:

```
WITH w AS
(
    SELECT * FROM big_table
)
SELECT * FROM w WHERE key =
123;
```

This `WITH` query will be folded, producing the same execution plan as:

```
SELECT * FROM big_table WHERE key = 123;
```

In particular, if there's an index on `key`, WarehousePG uses it to fetch just the rows having `key = 123`. On the other hand, in:

```
WITH w AS
(
    SELECT * FROM big_table
)
SELECT * FROM w AS w1 JOIN w AS w2 ON w1.key =
w2.ref
WHERE w2.key =
123;
```

the `WITH` query will be materialized, producing a temporary copy of `big_table` that is then joined with itself — without benefit of any index. This query will run much more efficiently if written as:

```
WITH w AS NOT MATERIALIZED
(
    SELECT * FROM big_table
)
SELECT * FROM w AS w1 JOIN w AS w2 ON w1.key =
w2.ref
WHERE w2.key =
123;
```

so that the parent query's restrictions can be applied directly to scans of `big_table`.

An example where `NOT MATERIALIZED` could be undesirable is:

```
WITH w AS
(
    SELECT key, very_expensive_function(val) as f FROM
some_table
)
SELECT * FROM w AS w1 JOIN w AS w2 ON w1.f =
w2.f;
```

Here, materialization of the `WITH` query ensures that WarehousePG evaluations `very_expensive_function` only once per table row, not twice.

Data-Modifying Statements in a WITH clause

For a `SELECT` command, you can use the data-modifying commands `INSERT`, `UPDATE`, or `DELETE` in a `WITH` clause. This allows you to perform several different operations in the same query.

A data-modifying statement in a `WITH` clause is run exactly once, and always to completion, independently of whether the primary query reads all (or indeed any) of the output. This is different from the rule when using `SELECT` in a `WITH` clause, the execution of a `SELECT` continues only as long as the primary query demands its output.

This simple CTE query deletes rows from `products`. The `DELETE` in the `WITH` clause deletes the specified rows from products, returning their contents by means of its `RETURNING` clause.

```
WITH deleted_rows AS (
    DELETE FROM products
    WHERE
        "date" >= '2010-10-01' AND
        "date" < '2010-11-01'
    RETURNING *
)
SELECT * FROM deleted_rows;
```

Data-modifying statements in a `WITH` clause must have `RETURNING` clauses, as shown in the previous example. It is the output of the `RETURNING` clause, *not* the target table of the data-modifying statement, that forms the temporary table that can be referred to by the rest of the query. If a data-modifying statement in a `WITH` lacks a `RETURNING` clause, then it forms no temporary table and cannot be referred to in the rest of the query. WarehousePG runs such a statement nonetheless.

If the optional `RECURSIVE` keyword is enabled, recursive self-references in data-modifying statements are not allowed. In some cases it is possible to work around this limitation by referring to the output of a recursive `WITH`. For example, this query would remove all direct and indirect subparts of a product:

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```
WITH RECURSIVE included_parts(sub_part, part) AS (
    SELECT sub_part, part FROM parts WHERE part = 'our_product'
  UNION ALL
    SELECT p.sub_part, p.part
    FROM included_parts pr, parts p
    WHERE p.part = pr.sub_part
  )
DELETE FROM parts
  WHERE part IN (SELECT part FROM included_parts);
```

The sub-statements in a `WITH` clause are run concurrently with each other and with the main query. Therefore, when using a data-modifying statement in a `WITH` , the order in which the specified updates actually happen is unpredictable. All of the statements are run wth the same *snapshot*. The effects of the statement are not visible on the target tables. This alleviates the effects of the unpredictability of the actual order of row updates, and means thats the `RETURNING` data is the only way to communicate changes between different `WITH` sub-statements and the main query.

In this example, the outer `SELECT` returns the original prices before the action of the `UPDATE` in the `WITH` clause:

```
WITH t AS (
    UPDATE products SET price = price * 1.05
    RETURNING *
)
SELECT * FROM products;
```

In this example, the outer `SELECT` returns the updated data:

```
WITH t AS (
    UPDATE products SET price = price * 1.05
    RETURNING *
)
SELECT * FROM t;
```

Updating the same row twice in a single statement is not supported. The effects of such a statement will not be predictable. Only one of the modifications takes place, but it is not easy (and sometimes not possible) to predict which modification occurs.

Any table used as the target of a data-modifying statement in a `WITH` clause must not have a conditional rule, nor an `ALSO` rule, nor an `INSTEAD` rule that expands to multiple statements.

Considerations

When constructing `WITH` queries, keep the following in mind:

- `SELECT FOR UPDATE` cannot be inlined.
- WarehousePG inlines multiply-referenced CTEs only when requested (by specifying `NOT MATERIALIZED`).
- Multiply-referenced CTEs cannot be inlined if they contain outer self-references.
- WarehousePG does not inline when the CTE includes a volatile function.
- An `ORDER BY` in the subquery or CTE does not force an ordering for the whole query.
- WarehousePG always materializes a CTE term in a query. Due to this:
    - A query that should touch a small amount of data may instead read a whole table, and possibly spill to a temporary file.
    - `UPDATE` or `DELETE FROM` statements are not permitted in a CTE term, as it acts more like a read-only temporary table than a dynamic view.
- While inlining is generally a huge win, there are certain boundary cases where it is not; for example, when a non-trivial expression will be inlined in multiple places.
- The GPORCA query optimizer does not support `[NOT] MATERIALIZED`.

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4.6.5 Using Functions and Operators

Description of user-defined and built-in functions and operators in WarehousePG.

- Using Functions in WarehousePG
- User-Defined Functions
- User-Defined Procedures
- Built-in Functions and Operators
- Window Functions
- Advanced Aggregate Functions

Parent topic: SQL: Querying Data

Using Functions in WarehousePG

When you invoke a function in WarehousePG, function attributes control the execution of the function. The volatility attributes (`IMMUTABLE`, `STABLE`, `VOLATILE`) and the `EXECUTE ON` attributes control two different aspects of function execution. In general, volatility indicates when the function is run, and `EXECUTE ON` indicates where it is run. The volatility attributes are PostgreSQL based attributes, the `EXECUTE ON` attributes are WarehousePG attributes.

For example, a function defined with the `IMMUTABLE` attribute can be run at query planning time, while a function with the `VOLATILE` attribute must be run for every row in the query. A function with the `EXECUTE ON COORDINATOR` attribute runs only on the coordinator instance, and a function with the `EXECUTE ON ALL SEGMENTS` attribute runs on all primary segment instances (not the coordinator).

These tables summarize what WarehousePG assumes about function execution based on the attribute.

Function Attribute	WarehousePG Support	Description	Comments
IMMUTABLE	Yes	Relies only on information directly in its argument list. Given the same argument values, always returns the same result.	
STABLE	Yes, in most cases	Within a single table scan, returns the same result for same argument values, but results change across SQL statements.	Results depend on database lookups or parameter values. `current_timestamp` family of functions is `STABLE`; values do not change within an execution.
VOLATILE	Restricted	Function values can change within a single table scan. For example: `random()`, `timeofday()`. This is the default attribute.	Any function with side effects is volatile, even if its result is predictable. For example: `setval()`.

Function Attribute	Description	Comments
EXECUTE ON ANY	Indicates that the function can be run on the coordinator, or any segment instance, and it returns the same result regardless of where it runs. This is the default attribute.	WarehousePG determines where the function runs.
EXECUTE ON COORDINATOR	Indicates that the function must be run on the coordinator instance.	Specify this attribute if the user-defined function runs queries to access tables.
EXECUTE ON ALL SEGMENTS	Indicates that for each invocation, the function must be run on all primary segment instances, but not the coordinator.	
EXECUTE ON INITPLAN	Indicates that the function contains an SQL command that dispatches queries to the segment instances and requires special processing on the coordinator instance by WarehousePG when possible.	

You can display the function volatility and `EXECUTE ON` attribute information with the psql `\df+ function` command.

Refer to the PostgreSQL Function Volatility Categories documentation for additional information about the WarehousePG function volatility classifications.

For more information about `EXECUTE ON` attributes, see CREATE FUNCTION.

In WarehousePG, data is divided up across segments — each segment is a distinct PostgreSQL database. To prevent inconsistent or unexpected results, do not run functions classified as `VOLATILE` at the segment level if they contain SQL commands or modify the database in any way. For example, functions such as `setval()` are not allowed to run on distributed data in WarehousePG because they can cause inconsistent data between segment instances.

A function can run read-only queries on replicated tables (`DISTRIBUTED REPLICATED`) on the segments, but any SQL command that modifies data must run on the coordinator instance.

> **Note** The hidden system columns (`ctid`, `cmin`, `cmax`, `xmin`, `xmax`, and `gp_segment_id`) cannot be referenced in user queries on replicated tables because they have no single, unambiguous value. WarehousePG returns a `column does not exist` error for the query.

To ensure data consistency, you can safely use `VOLATILE` and `STABLE` functions in statements that are evaluated on and run from the coordinator. For example, the following statements run on the coordinator (statements without a `FROM` clause):

```
SELECT setval('myseq', 201);
SELECT foo();
```

If a statement has a `FROM` clause containing a distributed table *and* the function in the `FROM` clause returns a set of rows, the statement can run on the segments:

```
SELECT * from foo();
```

WarehousePG does not support functions that return a table reference (`rangeFuncs`) or functions that use the `refCursor` data type.

Function Volatility and Plan Caching

There is relatively little difference between the `STABLE` and `IMMUTABLE` function volatility categories for simple interactive queries that are planned and immediately run. It does not matter much whether a function is run once during planning or once during query execution start up. But there is a big difference when you save the plan and reuse it later. If you mislabel a function `IMMUTABLE`, WarehousePG may prematurely fold it to a constant during planning, possibly reusing a stale value during subsequent execution of the plan. You may run into this hazard when using `PREPARE`d statements, or when using languages such as PL/pgSQL that cache plans.

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User-Defined Functions

WarehousePG supports user-defined functions. See Extending SQL in the PostgreSQL documentation for more information.

Use the `CREATE FUNCTION` statement to register user-defined functions that are used as described in Using Functions in WarehousePG. By default, user-defined functions are declared as `VOLATILE`, so if your user-defined function is `IMMUTABLE` or `STABLE`, you must specify the correct volatility level when you register your function.

By default, user-defined functions are declared as `EXECUTE ON ANY`. A function that runs queries to access tables is supported only when the function runs on the coordinator instance, except that a function can run `SELECT` commands that access only replicated tables on the segment instances. A function that accesses hash-distributed or randomly distributed tables must be defined with the `EXECUTE ON COORDINATOR` attribute. Otherwise, the function might return incorrect results when the function is used in a complicated query. Without the attribute, planner optimization might determine it would be beneficial to push the function invocation to segment instances.

When you create user-defined functions, avoid using fatal errors or destructive calls. WarehousePG may respond to such errors with a sudden shutdown or restart.

In WarehousePG, the shared library files for user-created functions must reside in the same library path location on every host in the WarehousePG cluster (coordinators, segments, and mirrors).

You can also create and run anonymous code blocks that are written in a WarehousePG procedural language such as PL/pgSQL. The anonymous blocks run as transient anonymous functions. For information about creating and running anonymous blocks, see the `DO` command.

User-Defined Procedures

A procedure is a database object similar to a function. The key differences are:

- You define a procedure with the CREATE PROCEDURE command, not `CREATE FUNCTION`.
- Procedures do not return a function value; hence `CREATE PROCEDURE` lacks a `RETURNS` clause. However, procedures can instead return data to their callers via output parameters.
- While a function is called as part of a query or DML command, you call a procedure in isolation using the CALL command.
- A procedure can commit or roll back transactions during its execution (then automatically beginning a new transaction), so long as the invoking `CALL` command is not part of an explicit transaction block. A function cannot do that.
- Certain function attributes, such as strictness, don't apply to procedures. Those attributes control how the function is used in a query, which isn't relevant to procedures.

Collectively, functions and procedures are also known as routines. There are commands such as ALTER ROUTINE and DROP ROUTINE that can operate on functions and procedures without having to know which kind it is. Note, however, that there is no `CREATE ROUTINE` command.

Built-in Functions and Operators

The following table lists the categories of built-in functions and operators supported by PostgreSQL. All functions and operators are supported in WarehousePG as in PostgreSQL with the exception of `STABLE` and `VOLATILE` functions, which are subject to the restrictions noted in Using Functions in WarehousePG. See the Functions and Operators section of the PostgreSQL documentation for more information about these built-in functions and operators.

WarehousePG includes JSON processing functions that manipulate values the `json` data type. For information about JSON data, see Working with JSON Data.

Table 3. Built-in functions and operators

Operator/Function Category	VOLATILE Functions	STABLE Functions	Restrictions
Logical Operators			
Comparison Operators			
Mathematical Functions and Operators	random setseed		
String Functions and Operators	*All built-in conversion functions*	convert pg_client_encoding	
Binary String Functions and Operators			
Bit String Functions and Operators			
Pattern Matching			
Data Type Formatting Functions		to_char to_timestamp	
Date/Time Functions and Operators	timeofday	age current_date current_time current_timestamp localtime localtimestamp now	
Enum Support Functions			
Geometric Functions and Operators			
Network Address Functions and Operators			
Sequence Manipulation Functions	nextval() setval()		

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Operator/Function Category	VOLATILE Functions	STABLE Functions	Restrictions
Conditional Expressions			
Array Functions and Operators		*All array functions*	
Aggregate Functions			
Subquery Expressions			
Row and Array Comparisons			
Set Returning Functions	generate_series		
System Information Functions		*All session information functions* *All access privilege inquiry functions* *All schema visibility inquiry functions* *All system catalog information functions* *All comment information functions* *All transaction ids and snapshots*	
System Administration Functions	set_config pg_cancel_backend pg_terminate_backend pg_reload_conf pg_rotate_logfile pg_start_backup pg_stop_backup pg_size_pretty pg_ls_dir pg_read_file pg_stat_file	current_setting *All database object size functions*	**Note:** The function `pg_column_size` displays bytes required to store the value, possibly with TOAST compression.
		cursor_to_xml(cursor refcursor, count int, nulls boolean, tableforest boolean, targetns text) cursor_to_xmlschema(cursor refcursor, nulls boolean, tableforest boolean, targetns text) database_to_xml(nulls boolean, tableforest boolean, targetns text) database_to_xmlschema(nulls boolean, tableforest boolean, targetns text) database_to_xml_and_xmlschema(nulls boolean, tableforest boolean, targetns text) query_to_xml(query text, nulls boolean, tableforest boolean, targetns text) query_to_xmlschema(query text, nulls boolean, tableforest boolean, targetns text) query_to_xml_and_xmlschema(query text, nulls boolean, tableforest boolean, targetns text) schema_to_xml(schema name, nulls boolean, tableforest boolean, targetns text) schema_to_xmlschema(schema name, nulls boolean, tableforest boolean, targetns text) schema_to_xml_and_xmlschema(schema name, nulls boolean, tableforest boolean, targetns text) table_to_xml(tbl regclass, nulls boolean, tableforest boolean, targetns text) table_to_xmlschema(tbl regclass, nulls boolean, tableforest boolean, targetns text)	

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Operator/Function Category	VOLATILE Functions	STABLE Functions	Restrictions
XML Functions and function-like expressions		table_to_xml_and_xmlschema(tbl regclass, nulls boolean, tableforest boolean, targetns text) xmlagg(xml) xmlconcat(xml[, ...]) xmlelement(name name [, xmlattributes(value [AS attname] [, ...])] [, content, ...]) xmlexists(text, xml) xmlforest(content [AS name] [, ...]) xml_is_well_formed(text) xml_is_well_formed_document(text) xml_is_well_formed_content(text) xmlparse ({ DOCUMENT | CONTENT } value) xpath(text, xml) xpath(text, xml, text[]) xpath_exists(text, xml) xpath_exists(text, xml, text[]) xmlpi(name target [, content]) xmlroot(xml, version text | no value [, standalone yes|no|no value]) xmlserialize ({ DOCUMENT | CONTENT } value AS type) xml(text) text(xml) xmlcomment(xml) xmlconcat2(xml, xml)	

Window Functions

The following built-in window functions are WarehousePG extensions to the PostgreSQL database. All window functions are *immutable*. For more information about window functions, see Window Expressions.

Table 4. Window functions

Function	Return Type	Full Syntax	Description
`cume_dist()`	`double precision`	`CUME_DIST() OVER ( [PARTITION BY` expr `] ORDER BY` expr `)`	Calculates the cumulative distribution of a value in a group of values. Rows with equal values always evaluate to the same cumulative distribution value.
`dense_rank()`	`bigint`	`DENSE_RANK () OVER ( [PARTITION BY` expr `] ORDER BY` expr `)`	Computes the rank of a row in an ordered group of rows without skipping rank values. Rows with equal values are given the same rank value.
`first_value(`*`expr`*`)`	same as input expr type	`FIRST_VALUE(` expr `) OVER ( [PARTITION BY` expr `] ORDER BY` expr `[ROWS|RANGE|GROUPS` frame_expr `] )`	Returns the first value in an ordered set of values.
`lag(`*`expr`* `[,`*`offset`*`] [,`*`default`*`])`	same as input *expr* type	`LAG(` *expr* `[,` *offset* `] [,` *default* `]) OVER ( [PARTITION BY` *expr* `] ORDER BY` *expr* `)`	Provides access to more than one row of the same table without doing a self join. Given a series of rows returned from a query and a position of the cursor, `LAG` provides access to a row at a given physical offset prior to that position. The default `offset` is 1. *default* sets the value that is returned if the offset goes beyond the scope of the window. If *default* is not specified, the default value is null.
`last_value(`*`expr`*`)`	same as input *expr* type	`LAST_VALUE(`*`expr`*`) OVER ( [PARTITION BY` *expr*`] ORDER BY` *expr* `[ROWS|RANGE|GROUPS` *frame_expr*`] )`	Returns the last value in an ordered set of values.
`lead(`*`expr`* `[,`*`offset`*`] [,`*`default`*`])`	same as input *expr* type	`LEAD(`*`expr`* `[,`*`offset`*`] [,`*`exprdefault`*`]) OVER ( [PARTITION BY` *expr*`] ORDER BY` *expr* `)`	Provides access to more than one row of the same table without doing a self join. Given a series of rows returned from a query and a position of the cursor, `lead` provides access to a row at a given physical offset after that position. If *offset* is not specified, the default offset is 1. *default* sets the value that is returned if the offset goes beyond the scope of the window. If *default* is not specified, the default value is null.

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Function	Return Type	Full Syntax	Description
`nth_value(expr)`	same as input *expr* type	`NTH_VALUE(expr) OVER ( [PARTITION BY expr] ORDER BY expr [ROWS|RANGE|GROUPS frame_expr] )`	Returns the value evaluated at the row that is the *nth* row of the window frame (counting from 1); null if no such row.
`ntile(expr)`	`bigint`	`NTILE(expr) OVER ( [PARTITION BY expr] ORDER BY expr )`	Divides an ordered data set into a number of buckets (as defined by *expr*) and assigns a bucket number to each row.
`percent_rank()`	`double precision`	`PERCENT_RANK () OVER ( [PARTITION BY expr] ORDER BY expr )`	Calculates the rank of a hypothetical row `R` minus 1, divided by 1 less than the number of rows being evaluated (within a window partition).
`rank()`	`bigint`	`RANK () OVER ( [PARTITION BY expr] ORDER BY expr )`	Calculates the rank of a row in an ordered group of values. Rows with equal values for the ranking criteria receive the same rank. The number of tied rows are added to the rank number to calculate the next rank value. Ranks may not be consecutive numbers in this case.
`row_number()`	`bigint`	`ROW_NUMBER () OVER ( [PARTITION BY expr] ORDER BY expr )`	Assigns a unique number to each row to which it is applied (either each row in a window partition or each row of the query).

Advanced Aggregate Functions

The following built-in advanced aggregate functions are WarehousePG extensions of the PostgreSQL database. These functions are *immutable*.

> **Note** The WarehousePG MADlib Extension for Analytics provides additional advanced functions to perform statistical analysis and machine learning with WarehousePG data. See WarehousePG MADlib Extension for Analytics in the *WarehousePG Reference Guide*.

Table 5. Advanced Aggregate Functions

Function	Return Type	Full Syntax	Description

`MEDIAN (expr)`	`timestamp, timestamptz, interval, float`	`MEDIAN (expression)`
		Example:
		`SELECT departmzent_id, MEDIAN(salary) FROM employees GROUP BY department_id;`
			Can take a two-dimensional array as input. Treats such arrays as matrices.

`sum(array[])`	`smallint[], int[], bigint[], float[]`	`sum(array[[1,2],[3,4]])`
		Example:
		`CREATE TABLE mymatrix (myvalue int[]); INSERT INTO mymatrix VALUES (array[[1,2],[3,4]]); INSERT INTO mymatrix VALUES (array[[0,1],[1,0]]); SELECT sum(myvalue) FROM mymatrix; sum \-\-\-\-\-\-\-\-\-\-\-\-\-\-\-\-\-\-\-\-\-\-\- {1,3},{4,4}`
			Performs matrix summation. Can take as input a two-dimensional array that is treated as a matrix.

`pivot_sum (label[], label, expr)`	`int[], bigint[], float[]`	`pivot_sum( array['A1','A2'], attr, value)`	A pivot aggregation using sum to resolve duplicate entries.
`unnest (array[])`	set of `anyelement`	`unnest( array['one', 'row', 'per', 'item'])`	Transforms a one dimensional array into rows. Returns a set of `anyelement`, a polymorphic pseudo-type in PostgreSQL.

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4.6.6 Working with JSON Data

WarehousePG supports JSON as specified in the RFC 7159 document and enforces data validity according to the JSON rules. There are also JSON-specific functions and operators available for the `json` and `jsonb` data types. See JSON Functions and Operators.

WarehousePG offers two types for storing JSON (JavaScript Object Notation) data: `json` and `jsonb`. To implement efficient query mechanisms for these data types, WarehousePG also provides the `jsonpath` data type described in jsonpath Type later in this topic.

This section contains the following topics:

- About JSON Data
- JSON Input and Output Syntax
- Designing JSON documents
- jsonb Containment and Existence
- jsonb Indexing
- Transforms
- jsonpath Type

Parent topic: SQL: Querying Data

About JSON Data

The `json` and `jsonb` data types accept *almost* identical sets of values as input. The major difference is one of efficiency.

- The `json` data type stores an exact copy of the input text. This requires JSON processing functions to reparse `json` data on each execution. The `json` data type does not alter the input text.
    - Semantically-insignificant white space between tokens is preserved, as well as the order of keys within JSON objects.
    - All key/value pairs are kept even if a JSON object contains duplicate keys. For duplicate keys, JSON processing functions consider the last value as the operative one.
- The `jsonb` data type stores a decomposed binary format of the input text. The conversion overhead makes data input slightly slower than the `json` data type. However, The JSON processing functions are significantly faster because reparsing `jsonb` data is not required. The `jsonb` data type alters the input text.
    - White space is not preserved.
    - The order of object keys is not preserved.
    - Duplicate object keys are not kept. If the input includes duplicate keys, only the last value is kept.
- The `jsonb` data type supports indexing. See jsonb Indexing.

In general, JSON data should be stored as the `jsonb` data type unless there are specialized needs, such as legacy assumptions about ordering of object keys.

WarehousePG allows only one character set encoding per database. It is therefore not possible for the JSON types to conform rigidly to the JSON specification unless the database encoding is UTF8. Attempts to directly include characters that cannot be represented in the database encoding will fail; conversely, characters that can be represented in the database encoding but not in UTF8 are allowed.

About Unicode Characters in JSON Data

The RFC 7159 document permits JSON strings to contain Unicode escape sequences denoted by `\uXXXX`.

- The WarehousePG input function for the `json` data type allows Unicode escapes regardless of the database encoding and checks Unicode escapes only for syntactic correctness (a `\u` followed by four hex digits).
- The WarehousePG input function for the `jsonb` data type is more strict. It does not allow Unicode escapes for non-ASCII characters (those above `U+007F`) unless the database encoding is UTF8. The `jsonb` type also rejects `\u0000`, which cannot be represented in the WarehousePG `text` type, and it requires that any use of Unicode surrogate pairs to designate characters outside the Unicode Basic Multilingual Plane be correct. Valid Unicode escapes, except for `\u0000`, are converted to the equivalent ASCII or UTF8 character for storage; this includes folding surrogate pairs into a single character.

> **Note** Many of the JSON processing functions described in JSON Functions and Operators convert Unicode escapes to regular characters and will therefore throw the same types of errors just described even if their input is of type `json` not `jsonb`. The fact that the `json` input function does not make these checks may be considered a historical artifact, although it does allow for simple storage (without processing) of JSON Unicode escapes in a non-UTF8 database encoding. In general, it is best to avoid mixing Unicode escapes in JSON with a non-UTF8 database encoding, if possible.

Mapping JSON Data Types to WarehousePG Data Types

When converting JSON text input into `jsonb` data, the primitive data types described by RFC 7159 are effectively mapped onto native WarehousePG data types, as shown in the following table.

JSON primitive data type	WarehousePG data type	Notes
`string`	`text`	`\u0000` is not allowed. Non-ASCII Unicode escapes are allowed only if database encoding is UTF8
`number`	`numeric`	`NaN` and `infinity` values are disallowed
`boolean`	`boolean`	Only lowercase `true` and `false` spellings are accepted
`null`	(none)	The JSON `null` primitive type is different than the SQL `NULL`

There are some minor constraints on what constitutes valid `jsonb` data that do not apply to the `json` data type, nor to JSON in the abstract, corresponding to limits on what can be represented by the underlying data type. Notably, when converting data to the `jsonb` data type, numbers that are outside the range of the WarehousePG `numeric` data type are rejected, while the `json` data type does not reject such numbers.

Such implementation-defined restrictions are permitted by RFC 7159. However, in practice such problems might occur in other implementations, as it is common to represent the JSON `number` primitive type as IEEE 754 double precision floating point (which RFC 7159 explicitly anticipates and allows for).

When using JSON as an interchange format with other systems, be aware of the possibility of losing numeric precision compared to data originally stored by WarehousePG.

Also, as noted in the previous table, there are some minor restrictions on the input format of JSON primitive types that do not apply to the corresponding WarehousePG data types.

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JSON Input and Output Syntax

The input and output syntax for the `json` data type is as specified in RFC 7159.

The following are all valid `json` (or `jsonb`) expressions:

```
-- Simple scalar/primitive value
-- Primitive values can be numbers, quoted strings, true, false, or null
SELECT '5'::json;

-- Array of zero or more elements (elements need not be of same type)
SELECT '[1, 2, "foo", null]'::json;

-- Object containing pairs of keys and values
-- Note that object keys must always be quoted strings
SELECT '{"bar": "baz", "balance": 7.77, "active": false}'::json;

-- Arrays and objects can be nested arbitrarily
SELECT '{"foo": [true, "bar"], "tags": {"a": 1, "b": null}}'::json;
```

As previously stated, when a JSON value is input and then printed without any additional processing, the `json` data type outputs the same text that was input, while the `jsonb` data type does not preserve semantically-insignificant details such as whitespace. For example, note the differences here:

```
SELECT '{"bar": "baz", "balance": 7.77, "active":false}'::json;
                      json
-------------------------------------------------
 {"bar": "baz", "balance": 7.77, "active":false}
(1 row)

SELECT '{"bar": "baz", "balance": 7.77, "active":false}'::jsonb;
                      jsonb
-------------------------------------------------
 {"bar": "baz", "active": false, "balance": 7.77}
(1 row)
```

One semantically-insignificant detail worth noting is that with the `jsonb` data type, numbers will be printed according to the behavior of the underlying `numeric` type. In practice, this means that numbers entered with `E` notation will be printed without it, for example:

```
SELECT '{"reading": 1.230e-5}'::json, '{"reading": 1.230e-5}'::jsonb;
         json          |          jsonb
-----------------------+-------------------------
 {"reading": 1.230e-5} | {"reading": 0.00001230}
(1 row)
```

However, the `jsonb` data type preserves trailing fractional zeroes, as seen in previous example, even though those are semantically insignificant for purposes such as equality checks.

Designing JSON documents

Representing data as JSON can be considerably more flexible than the traditional relational data model, which is compelling in environments where requirements are fluid. It is quite possible for both approaches to co-exist and complement each other within the same application. However, even for applications where maximal flexibility is desired, it is still recommended that JSON documents have a somewhat fixed structure. The structure is typically unenforced (though enforcing some business rules declaratively is possible), but having a predictable structure makes it easier to write queries that usefully summarize a set of JSON documents (datums) in a table.

JSON data is subject to the same concurrency-control considerations as any other data type when stored in a table. Although storing large documents is practicable, keep in mind that any update acquires a row-level lock on the whole row. Consider limiting JSON documents to a manageable size in order to decrease lock contention among updating transactions. Ideally, JSON documents should each represent an atomic datum that business rules dictate cannot reasonably be further subdivided into smaller datums that could be modified independently.

jsonb Containment and Existence

Testing *containment* is an important capability of `jsonb`. There is no parallel set of facilities for the `json` type. Containment tests whether one `jsonb` document has contained within it another one. These examples return `true` except as noted:

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```
-- Simple scalar/primitive values contain only the identical value:
SELECT '"foo"'::jsonb @> '"foo"'::jsonb;

-- The array on the right side is contained within the one on the left:
SELECT '[1, 2, 3]'::jsonb @> '[1, 3]'::jsonb;

-- Order of array elements is not significant, so this is also true:
SELECT '[1, 2, 3]'::jsonb @> '[3, 1]'::jsonb;

-- Duplicate array elements don't matter either:
SELECT '[1, 2, 3]'::jsonb @> '[1, 2, 2]'::jsonb;

-- The object with a single pair on the right side is contained
-- within the object on the left side:
SELECT '{"product": "WarehousePG", "version": "7.0.0", "jsonb":true}'::jsonb @> '{"version":"7.0.0"}'::jsonb;

-- The array on the right side is not considered contained within the
-- array on the left, even though a similar array is nested within it:
SELECT '[1, 2, [1, 3]]'::jsonb @> '[1, 3]'::jsonb;  -- yields false

-- But with a layer of nesting, it is contained:
SELECT '[1, 2, [1, 3]]'::jsonb @> '[[1, 3]]'::jsonb;

-- Similarly, containment is not reported here:
SELECT '{"foo": {"bar": "baz"}}'::jsonb @> '{"bar": "baz"}'::jsonb; -- yields false

-- But with a layer of nesting, it is contained:
SELECT '{"foo": {"bar": "baz"}}'::jsonb @> '{"foo": {}}'::jsonb;
```

The general principle is that the contained object must match the containing object as to structure and data contents, possibly after discarding some non-matching array elements or object key/value pairs from the containing object. For containment, the order of array elements is not significant when doing a containment match, and duplicate array elements are effectively considered only once.

As an exception to the general principle that the structures must match, an array may contain a primitive value:

```
-- This array contains the primitive string value:
SELECT '["foo", "bar"]'::jsonb @> '"bar"'::jsonb;

-- This exception is not reciprocal -- non-containment is reported here:
SELECT '"bar"'::jsonb @> '["bar"]'::jsonb;  -- yields false
```

`jsonb` also has an *existence* operator, which is a variation on the theme of containment: it tests whether a string (given as a `text` value) appears as an object key or array element at the top level of the `jsonb` value. These examples return `true` except as noted:

```
-- String exists as array element:
SELECT '["foo", "bar", "baz"]'::jsonb ? 'bar';

-- String exists as object key:
SELECT '{"foo": "bar"}'::jsonb ? 'foo';

-- Object values are not considered:
SELECT '{"foo": "bar"}'::jsonb ? 'bar';  -- yields false

-- As with containment, existence must match at the top level:
SELECT '{"foo": {"bar": "baz"}}'::jsonb ? 'bar'; -- yields false

-- A string is considered to exist if it matches a primitive JSON string:
SELECT '"foo"'::jsonb ? 'foo';
```

JSON objects are better suited than arrays for testing containment or existence when there are many keys or elements involved, because unlike arrays they are internally optimized for searching, and do not need to be searched linearly.

Because JSON containment is nested, an appropriate query can skip explicit selection of sub-objects. As an example, suppose that we have a `doc` column containing objects at the top level, with most objects containing `tags` fields that contain arrays of sub-objects. This query finds entries in which sub-objects containing both `"term":"paris"` and `"term":"food"` appear, while ignoring any such keys outside the `tags` array:

```
SELECT doc->'site_name' FROM websites
  WHERE doc @> '{"tags":[{"term":"paris"}, {"term":"food"}]}';
```

The query with this predicate could accomplish the same thing:

```
SELECT doc->'site_name' FROM websites
  WHERE doc->'tags' @> '[{"term":"paris"}, {"term":"food"}]';
```

However, the second approach is less flexible and is often less efficient as well.

On the other hand, the JSON existence operator is not nested: it will only look for the specified key or array element at top level of the JSON value.

The various containment and existence operators, along with all other JSON operators and functions are documented in JSON Functions and Operators.

jsonb Indexing

The WarehousePG `jsonb` data type, supports GIN, btree, and hash indexes.

- GIN Indexes on jsonb Data
- Btree and Hash Indexes on jsonb Data

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GIN Indexes on jsonb Data

GIN indexes can be used to efficiently search for keys or key/value pairs occurring within a large number of `jsonb` documents (datums). Two GIN operator classes are provided, offering different performance and flexibility trade-offs.

The default GIN operator class for jsonb supports queries with the `@>`, `?`, `?&` and `?|` operators. (For details of the semantics that these operators implement, see JSON Operators.) An example of creating an index with this operator class is:

```
CREATE INDEX idxgin ON api USING GIN (jdoc);
```

The non-default GIN operator class `jsonb_path_ops` does not support the key-exists operators, but it does support `@>`, `@?`, and `@@`. An example of creating an index with this operator class is:

```
CREATE INDEX idxginp ON api USING GIN (jdoc jsonb_path_ops);
```

Consider the example of a table that stores JSON documents retrieved from a third-party web service, with a documented schema definition. This is a typical document:

```
{
    "guid": "9c36adc1-7fb5-4d5b-83b4-90356a46061a",
    "name": "Angela Barton",
    "is_active": true,
    "company": "Magnafone",
    "address": "178 Howard Place, Gulf, Washington, 702",
    "registered": "2009-11-07T08:53:22 +08:00",
    "latitude": 19.793713,
    "longitude": 86.513373,
    "tags": [
        "enim",
        "aliquip",
        "qui"
    ]
}
```

The JSON documents are stored a table named `api`, in a `jsonb` column named `jdoc`. If a GIN index is created on this column, queries like the following can make use of the index:

```
-- Find documents in which the key "company" has value "Magnafone"
SELECT jdoc->'guid', jdoc->'name' FROM api WHERE jdoc @> '{"company": "Magnafone"}';
```

However, the index could not be used for queries like the following. The operator `?` is indexable, however, the comparison is not applied directly to the indexed column `jdoc`:

```
-- Find documents in which the key "tags" contains key or array element "qui"
SELECT jdoc->'guid', jdoc->'name' FROM api WHERE jdoc -> 'tags' ? 'qui';
```

With appropriate use of expression indexes, the above query can use an index. If querying for particular items within the `tags` key is common, defining an index like this might be worthwhile:

```
CREATE INDEX idxgintags ON api USING GIN ((jdoc -> 'tags'));
```

Now, the `WHERE` clause `jdoc -> 'tags' ? 'qui'` is recognized as an application of the indexable operator `?` to the indexed expression `jdoc -> 'tags'`. For information about expression indexes, see Indexes on Expressions.

Another approach to querying JSON documents is to exploit containment, for example:

```
-- Find documents in which the key "tags" contains array element "qui"
SELECT jdoc->'guid', jdoc->'name' FROM api WHERE jdoc @> '{"tags": ["qui"]}';
```

A simple GIN index on the `jdoc` column can support this query. However, the index will store copies of every key and value in the `jdoc` column, whereas the expression index of the previous example stores only data found under the `tags` key. While the simple-index approach is far more flexible (since it supports queries about any key), targeted expression indexes are likely to be smaller and faster to search than a simple index.

GIN indexes also support the `@?` and `@@` operators, which perform `jsonpath` matching. Examples are:

```
SELECT jdoc->'guid', jdoc->'name' FROM api WHERE jdoc @? '$.tags[*] ? (@ == "qui")';
```

```
SELECT jdoc->'guid', jdoc->'name' FROM api WHERE jdoc @@ '$.tags[*] == "qui"';
```

For these operators, a GIN index extracts clauses of the form `accessors_chain = constant` out of the `jsonpath` pattern, and does the index search based on the keys and values mentioned in these clauses. The accessors chain may include `.key`, `[*]`, and `[index]` accessors. The `jsonb_ops` operator class also supports `.*` and `.**` accessors, but the `jsonb_path_ops` operator class does not.

Although the `jsonb_path_ops` operator class supports only queries with the `@>`, `@?` and `@@` operators, it has notable performance advantages over the default operator class `jsonb_ops`. A `jsonb_path_ops` index is usually much smaller than a `jsonb_ops` index over the same data, and the specificity of searches is better, particularly when queries contain keys that appear frequently in the data. Therefore search operations typically perform better than with the default operator class.

The technical difference between a `jsonb_ops` and a `jsonb_path_ops` GIN index is that the former creates independent index items for each key and value in the data, while the latter creates index items only for each value in the data.

> **Note** For this discussion, the term *value* includes array elements, though JSON terminology sometimes considers array elements distinct from values within objects.

Basically, each `jsonb_path_ops` index item is a hash of the value and the key(s) leading to it; for example to index `{"foo": {"bar": "baz"}}`, a single index item would be created incorporating all three of `foo`, `bar`, and `baz` into the hash value. Thus a containment query looking for this structure would result in an extremely specific index search; but there is no way at all to find out whether `foo` appears as a key. On the other hand, a `jsonb_ops` index would create three index items representing `foo`, `bar`, and `baz` separately; then to do the containment query, it would look for rows containing all three of these items. While GIN indexes can perform such an `AND` search fairly efficiently, it will still be less specific and slower than the equivalent `jsonb_path_ops` search, especially if there are a very large number of rows containing any single one of the three index items.

A disadvantage of the `jsonb_path_ops` approach is that it produces no index entries for JSON structures not containing any values, such as `{"a": {}}`. If a search for documents containing such a structure is requested, it will require a full-index scan, which is quite slow. `jsonb_path_ops` is ill-suited for applications that often perform such searches.

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Btree and Hash Indexes on jsonb Data

`jsonb` also supports `btree` and `hash` indexes. These are usually useful only when it is important to check the equality of complete JSON documents.

For completeness, the `btree` ordering for `jsonb` datums is:

```
Object > Array > Boolean > Number > String > Null

Object with n pairs > object with n - 1 pairs

Array with n elements > array with n - 1 elements
```

Objects with equal numbers of pairs are compared in the order:

```
key-1, value-1, key-2 ...
```

Object keys are compared in their storage order. In particular, since shorter keys are stored before longer keys, this can lead to orderings that might not be intuitive, such as:

```
{ "aa": 1, "c": 1} > {"b": 1, "d": 1}
```

Similarly, arrays with equal numbers of elements are compared in the order:

```
element-1, element-2 ...
```

Primitive JSON values are compared using the same comparison rules as for the underlying WarehousePG data type. Strings are compared using the default database collation.

Transforms

Additional extensions are available that implement transforms for the `jsonb` type for different procedural languages.

The extensions for PL/Perl are called `jsonb_plperl` and j `sonb_plperlu` . If you use them, `jsonb` values are mapped to Perl arrays, hashes, and scalars, as appropriate.

The extension for PL/Python is called `jsonb_plpython3u` . If you use it, `jsonb` values are mapped to Python dictionaries, lists, and scalars, as appropriate.

jsonpath Type

The `jsonpath` type implements support for the SQL/JSON path language in WarehousePG to efficiently query JSON data. It provides a binary representation of the parsed SQL/JSON path expression that specifies the items to be retrieved by the path engine from the JSON data for further processing with the SQL/JSON query functions.

The semantics of SQL/JSON path predicates and operators generally follow SQL. At the same time, to provide a most natural way of working with JSON data, SQL/JSON path syntax uses some of the JavaScript conventions:

- Dot (`.`) is used for member access.
- Square brackets (`[]`) are used for array access.
- SQL/JSON arrays are 0-relative, unlike regular SQL arrays that start from 1.

An SQL/JSON path expression is typically written in an SQL query as an SQL character string literal, so it must be enclosed in single quotes, and any single quotes desired within the value must be doubled. Some forms of path expressions require string literals within them. These embedded string literals follow JavaScript/ECMAScript conventions: they must be surrounded by double quotes, and backslash escapes may be used within them to represent otherwise-hard-to-type characters. In particular, the way to write a double quote within an embedded string literal is `\"` , and to write a backslash itself, you must write `\\` . Other special backslash sequences include those recognized in JSON strings: `\b` , `\f` , `\n` , `\r` , `\t` , `\v` for various ASCII control characters, and `\uNNNN` for a Unicode character identified by its 4-hex-digit code point. The backslash syntax also includes two cases not allowed by JSON: `\xNN` for a character code written with only two hex digits, and `\u{N...}` for a character code written with 1 to 6 hex digits.

A path expression consists of a sequence of path elements, which can be the following:

- Path literals of JSON primitive types: Unicode text, numeric, true, false, or null.
- Path variables listed in the **jsonpath Variables** table below.
- Accessor operators listed in the **jsonpath Accessors** table below.
- `jsonpath` operators and methods listed in SQL/JSON Path Operators and Methods.
- Parentheses, which can be used to provide filter expressions or define the order of path evaluation.

For details on using `jsonpath` expressions with SQL/JSON query functions, see SQL/JSON Filter Expression Elements.

`jsonpath` Variables

Variable	Description
`$`	A variable representing the JSON text to be queried (the *context item*).
`$varname`	A named variable. Its value can be set by the parameter `vars` of several JSON processing functions. See JSON Processing Functions and its notes for details.
`@`	A variable representing the result of path evaluation in filter expressions.

`jsonpath` Accessors

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Accessor Operator	Description

`. key`
 	
`."$ varname "`
	Member accessor that returns an object member with the specified key. If the key name is a named variable starting with `$` or does not meet the JavaScript rules of an identifier, it must be enclosed in double quotes as a character string literal.

`.*`	Wildcard member accessor that returns the values of all members located at the top level of the current object.
`.**`	Recursive wildcard member accessor that processes all levels of the JSON hierarchy of the current object and returns all the member values, regardless of their nesting level. This is a WarehousePG extension of the SQL/JSON standard.

`.**{ level }`
 	
`.**{ start_level to end_level }`
	Same as `.**`, but with a filter over nesting levels of JSON hierarchy. Nesting levels are specified as integers. Zero level corresponds to the current object. To access the lowest nesting level, you can use the `last` keyword. This is a WarehousePG extension of the SQL/JSON standard.

`[ subscript , ...]`	Array element accessor. `subscript` can be given in two forms: `index` or `start_index to end_index`. The first form returns a single array element by its index. The second form returns an array slice by the range of indexes, including the elements that correspond to the provided `start_index` and `end_index`. The specified `index` can be an integer, as well as an expression returning a single numeric value, which is automatically cast to integer. Zero index corresponds to the first array element. You can also use the `last` keyword to denote the last array element, which is useful for handling arrays of unknown length.
`[*]`	Wildcard array element accessor that returns all array elements.

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4.6.7 Working with XML Data

WarehousePG supports the `xml` data type that stores XML data.

The `xml` data type checks the input values for well-formedness, providing an advantage over simply storing XML data in a text field. Additionally, support functions allow you to perform type-safe operations on this data; refer toXML Function Reference, below.

Use of this data type requires the installation to have been built with `configure --with-libxml`. This is enabled by default for WarehousePG builds.

The `xml` type can store well-formed "documents", as defined by the XML standard, as well as "content" fragments, which are defined by reference to the more permissivedocument node of the XQuery and XPath model. Roughly, this means that content fragments can have more than one top-level element or character node. The expression `xmlvalue IS DOCUMENT` can be used to evaluate whether a particular `xml` value is a full document or only a content fragment.

This section contains the following topics:

- Creating XML Values
- Encoding Handling
- Accessing XML Values
- Processing XML
- Mapping Tables to XML
- Using XML Functions and Expressions

Parent topic: SQL: Querying Data

Creating XML Values

To produce a value of type `xml` from character data, use the function `xmlparse`:

```
xmlparse ( { DOCUMENT | CONTENT } value)
```

For example:

```
XMLPARSE (DOCUMENT '<?xml version="1.0"?><book><title>Manual</title><chapter>...</chapter></book>')
XMLPARSE (CONTENT 'abc<foo>bar</foo><bar>foo</bar>')
```

The above method converts character strings into XML values according to the SQL standard, but you can also use WarehousePG syntax like the following:

```
xml '<foo>bar</foo>'
'<foo>bar</foo>'::xml
```

The `xml` type does not validate input values against a document type declaration (DTD), even when the input value specifies a DTD. There is also currently no built-in support for validating against other XML schema languages such as XML schema.

The inverse operation, producing a character string value from `xml`, uses the function `xmlserialize`:

```
xmlserialize ( { DOCUMENT | CONTENT } <value> AS <type> )
```

type can be `character`, `character varying`, or `text` (or an alias for one of those). Again, according to the SQL standard, this is the only way to convert between type `xml` and character types, but WarehousePG also allows you to simply cast the value.

When a character string value is cast to or from type `xml` without going through `XMLPARSE` or `XMLSERIALIZE`, respectively, the choice of `DOCUMENT` versus `CONTENT` is determined by the `XML OPTION` session configuration parameter, which can be set using the standard command:

```
SET XML OPTION { DOCUMENT | CONTENT };
```

or simply like WarehousePG:

```
SET XML OPTION TO { DOCUMENT | CONTENT };
```

The default is CONTENT, so all forms of XML data are allowed.

Encoding Handling

Be careful when dealing with multiple character encodings on the client, server, and in the XML data passed through them. When using the text mode to pass queries to the server and query results to the client (which is the normal mode), WarehousePG converts all character data passed between the client and the server, and vice versa, to the character encoding of the respective endpoint; see Character Set Support. This includes string representations of XML values, such as in the above examples. Ordinarily, this means that encoding declarations contained in XML data can become invalid, as the character data is converted to other encodings while travelling between client and server, because the embedded encoding declaration is not changed. To cope with this behavior, encoding declarations contained in character strings presented for input to the `xml` type are ignored, and content is assumed to be in the current server encoding. Consequently, for correct processing, character strings of XML data must be sent from the client in the current client encoding. It is the responsibility of the client to either convert documents to the current client encoding before sending them to the server, or to adjust the client encoding appropriately. On output, values of type `xml` will not have an encoding declaration, and clients should assume all data is in the current client encoding.

When using binary mode to pass query parameters to the server and query results back to the client, no character set conversion is performed, so the situation is different. In this case, an encoding declaration in the XML data will be observed, and if it is absent, the data will be assumed to be in UTF-8 (as required by the XML standard; note that WarehousePG does not support UTF-16). On output, data will have an encoding declaration specifying the client encoding, unless the client encoding is UTF-8, in which case it will be omitted.

> **Note** Processing XML data with WarehousePG will be less error-prone and more efficient if the XML data encoding, client encoding, and server encoding are the same. Because XML data is internally processed in UTF-8, computations will be most efficient if the server encoding is also UTF-8.

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Accessing XML Values

The `xml` data type is unusual in that it does not provide any comparison operators. This is because there is no well-defined and universally useful comparison algorithm for XML data. One consequence of this is that you cannot retrieve rows by comparing an `xml` column against a search value. XML values should therefore typically be accompanied by a separate key field such as an ID. An alternative solution for comparing XML values is to convert them to character strings first, but note that character string comparison has little to do with a useful XML comparison method.

Because there are no comparison operators for the `xml` data type, it is not possible to create an index directly on a column of this type. If speedy searches in XML data are desired, possible workarounds include casting the expression to a character string type and indexing that, or indexing an XPath expression. Of course, the actual query would have to be adjusted to search by the indexed expression.

Processing XML

To process values of data type `xml`, WarehousePG offers the functions `xpath` and `xpath_exists`, which evaluate XPath 1.0 expressions.

```
xpath(<xpath>, <xml> [, <nsarray>])
```

The function `xpath` evaluates the XPath expression `xpath` (a text value) against the XML value `xml`. It returns an array of XML values corresponding to the node set produced by the XPath expression.

The second argument must be a well formed XML document. In particular, it must have a single root node element.

The optional third argument of the function is an array of namespace mappings. This array should be a two-dimensional text array with the length of the second axis being equal to 2 (i.e., it should be an array of arrays, each of which consists of exactly 2 elements). The first element of each array entry is the namespace name (alias), the second the namespace URI. It is not required that aliases provided in this array be the same as those being used in the XML document itself (in other words, both in the XML document and in the `xpath` function context, aliases are local).

Example:

```
SELECT xpath('/my:a/<text>()', '<my:a xmlns:my="http://example.com">test</my:a>',
            ARRAY[ARRAY['my', 'http://example.com']]);

 xpath
--------
 {test}
(1 row)
```

To deal with default (anonymous) namespaces, do something like this:

```
SELECT xpath('//mydefns:b/<text>()', '<a xmlns="http://example.com"><b>test</b></a>',
            ARRAY[ARRAY['mydefns', 'http://example.com']]);

 xpath
--------
 {test}
(1 row)
```

```
xpath_exists(<xpath>, <xml> [, <nsarray>])
```

The function `xpath_exists` is a specialized form of the `xpath` function. Instead of returning the individual XML values that satisfy the XPath, this function returns a Boolean indicating whether the query was satisfied or not. This function is equivalent to the standard `XMLEXISTS` predicate, except that it also offers support for a namespace mapping argument.

Example:

```
SELECT xpath_exists('/my:a/<text>()', '<my:a xmlns:my="http://example.com">test</my:a>',
                    ARRAY[ARRAY['my', 'http://example.com']]);

 xpath_exists
--------------
 t
(1 row)
```

Mapping Tables to XML

The following functions map the contents of relational tables to XML values. They can be thought of as XML export functionality:

```
table_to_xml(tbl regclass, nulls boolean, tableforest boolean, targetns text)
query_to_xml(query <text>, nulls boolean, tableforest boolean, targetns text)
cursor_to_xml(cursor refcursor, count int, nulls boolean,
              tableforest boolean, targetns text)
```

The return type of each function is `xml`.

`table_to_xml` maps the content of the named table, passed as parameter `tbl`. The `regclass` type accepts strings identifying tables using the usual notation, including optional schema qualifications and double quotes. `query_to_xml` runs the query whose text is passed as parameter query and maps the result set. `cursor_to_xml` fetches the indicated number of rows from the cursor specified by the parameter cursor. This variant is recommended if large tables have to be mapped, because the result value is built up in memory by each function.

If `tableforest` is false, then the resulting XML document looks like this:

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```
<tablename>
  <row>
    <columnname1>data</columnname1>
    <columnname2>data</columnname2>
  </row>

  <row>
    ...
  </row>

  ...
</tablename>
```

If `tableforest` is true, the result is an XML content fragment that looks like this:

```
<tablename>
  <columnname1>data</columnname1>
  <columnname2>data</columnname2>
</tablename>

<tablename>
  ...
</tablename>

...
```

If no table name is available, that is, when mapping a query or a cursor, the string `table` is used in the first format, `row` in the second format.

The choice between these formats is up to the user. The first format is a proper XML document, which will be important in many applications. The second format tends to be more useful in the `cursor_to_xml` function if the result values are to be later reassembled into one document. The functions for producing XML content discussed above, in particular `xmlelement`, can be used to alter the results as desired.

The data values are mapped in the same way as described for the function `xmlelement`, above.

The parameter nulls determines whether null values should be included in the output. If true, null values in columns are represented as:

```
<columnname xsi:nil="true"/>
```

where `xsi` is the XML namespace prefix for XML schema Instance. An appropriate namespace declaration will be added to the result value. If false, columns containing null values are simply omitted from the output.

The parameter `targetns` specifies the desired XML namespace of the result. If no particular namespace is wanted, an empty string should be passed.

The following functions return XML schema documents describing the mappings performed by the corresponding functions above:

```
able_to_xmlschema(tbl regclass, nulls boolean, tableforest boolean, targetns text)
query_to_xmlschema(query <text>, nulls boolean, tableforest boolean, targetns text)
cursor_to_xmlschema(cursor refcursor, nulls boolean, tableforest boolean, targetns text)
```

It is essential that the same parameters are passed in order to obtain matching XML data mappings and XML schema documents.

The following functions produce XML data mappings and the corresponding XML schema in one document (or `forest`), linked together. They can be useful where self-contained and self-describing results are desired:

```
table_to_xml_and_xmlschema(tbl regclass, nulls boolean, tableforest boolean, targetns text)
query_to_xml_and_xmlschema(query <text>, nulls boolean, tableforest boolean, targetns text)
```

In addition, the following functions are available to produce analogous mappings of entire schemas or the entire current database:

```
schema_to_xml(schema name, nulls boolean, tableforest boolean, targetns text)
schema_to_xmlschema(schema name, nulls boolean, tableforest boolean, targetns text)
schema_to_xml_and_xmlschema(schema name, nulls boolean, tableforest boolean, targetns text)

database_to_xml(nulls boolean, tableforest boolean, targetns text)
database_to_xmlschema(nulls boolean, tableforest boolean, targetns text)
database_to_xml_and_xmlschema(nulls boolean, tableforest boolean, targetns text)
```

Note that these potentially produce large amounts of data, which needs to be built up in memory. When requesting content mappings of large schemas or databases, consider mapping the tables separately instead, possibly even through a cursor.

The result of a schema content mapping looks like this:

```
<schemaname>

table1-mapping

table2-mapping

...

</schemaname>
```

where the format of a table mapping depends on the `tableforest` parameter, as explained above.

The result of a database content mapping looks like this:

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```
<dbname>

<schema1name>
  ...
</schema1name>

<schema2name>
  ...
</schema2name>

...

</dbname>
```

where the schema mapping is as above.

The example below demonstrates using the output produced by these functions, The example shows an XSLT stylesheet that converts the output of `table_to_xml_and_xmlschema` to an HTML document containing a tabular rendition of the table data. In a similar manner, the results from these functions can be converted into other XML-based formats.

```
<?xml version="1.0"?>
<xsl:stylesheet version="1.0"
    xmlns:xsl="http://www.w3.org/1999/XSL/Transform"
    xmlns:xsd="http://www.w3.org/2001/XMLSchema"
    xmlns="http://www.w3.org/1999/xhtml"
>

  <xsl:output method="xml"
      doctype-system="http://www.w3.org/TR/xhtml1/DTD/xhtml1-strict.dtd"
      doctype-public="-//W3C/DTD XHTML 1.0 Strict//EN"
      indent="yes"/>

  <xsl:template match="/*">
    <xsl:variable name="schema" select="//xsd:schema"/>
    <xsl:variable name="tabletypename"
                  select="$schema/xsd:element[@name=name(current())]/@type"/>
    <xsl:variable name="rowtypename"
                  select="$schema/xsd:complexType[@name=$tabletypename]/xsd:sequence/xsd:element[@name='row']/@type"/>

    <html>
      <head>
        <title><xsl:value-of select="name(current())"/></title>
      </head>
      <body>
        <table>
          <tr>
            <xsl:for-each select="$schema/xsd:complexType[@name=$rowtypename]/xsd:sequence/xsd:element/@name">
              <th><xsl:value-of select="."/></th>
            </xsl:for-each>
          </tr>

          <xsl:for-each select="row">
            <tr>
              <xsl:for-each select="*">
                <td><xsl:value-of select="."/></td>
              </xsl:for-each>
            </tr>
          </xsl:for-each>
        </table>
      </body>
    </html>
  </xsl:template>

</xsl:stylesheet>
```

XML Function Reference

The functions described in this section operate on values of type `xml`. The section XML Predicatesalso contains information about the `xml` functions and function-like expressions.

Function:

`xmlcomment`

Synopsis:

```
xmlcomment(<text>)
```

The function `xmlcomment` creates an XML value containing an XML comment with the specified text as content. The text cannot contain "--" or end with a "-" so that the resulting construct is a valid XML comment. If the argument is null, the result is null.

Example:

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```
SELECT xmlcomment('hello');

  xmlcomment
--------------
 <!--hello-->
```

Function:

`xmlconcat`

Synopsis:

```
xmlconcat(xml[, …])
```

The function `xmlconcat` concatenates a list of individual XML values to create a single value containing an XML content fragment. Null values are omitted; the result is only null if there are no nonnull arguments.

Example:

```
SELECT xmlconcat('<abc/>', '<bar>foo</bar>');

      xmlconcat
----------------------
 <abc/><bar>foo</bar>
```

XML declarations, if present, are combined as follows:

- If all argument values have the same XML version declaration, that version is used in the result, else no version is used.
- If all argument values have the standalone declaration value "yes", then that value is used in the result.
- If all argument values have a standalone declaration value and at least one is "no", then that is used in the result. Otherwise, the result will have no standalone declaration.
- If the result is determined to require a standalone declaration but no version declaration, a version declaration with version 1.0 will be used because XML requires an XML declaration to contain a version declaration.

Encoding declarations are ignored and removed in all cases.

Example:

```
SELECT xmlconcat('<?xml version="1.1"?><foo/>', '<?xml version="1.1" standalone="no"?><bar/>');

            xmlconcat
-----------------------------------
 <?xml version="1.1"?><foo/><bar/>
```

Function:

`xmlelement`

Synopsis:

```
xmlelement(name name [, xmlattributes(value [AS attname] [, ... ])] [, content, ...])
```

The `xmlelement` expression produces an XML element with the given name, attributes, and content.

Examples:

```
SELECT xmlelement(name foo);

 xmlelement
------------
 <foo/>

SELECT xmlelement(name foo, xmlattributes('xyz' as bar));

    xmlelement
------------------
 <foo bar="xyz"/>

SELECT xmlelement(name foo, xmlattributes(current_date as bar), 'cont', 'ent');

             xmlelement
-------------------------------------
 <foo bar="2017-01-26">content</foo>
```

Element and attribute names that are not valid XML names are escaped by replacing the offending characters by the sequence `_xHHHH_`, where HHHH is the character's Unicode codepoint in hexadecimal notation. For example:

```
SELECT xmlelement(name "foo$bar", xmlattributes('xyz' as "a&b"));

            xmlelement
-----------------------------------
 <foo_x0024_bar a_x0026_b="xyz"/>
```

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An explicit attribute name need not be specified if the attribute value is a column reference, in which case the column's name will be used as the attribute name by default. In other cases, the attribute must be given an explicit name. So this example is valid:

```
CREATE TABLE test (a xml, b xml);
SELECT xmlelement(name test, xmlattributes(a, b)) FROM test;
```

But these are not:

```
SELECT xmlelement(name test, xmlattributes('constant'), a, b) FROM test;
SELECT xmlelement(name test, xmlattributes(func(a, b))) FROM test;
```

Element content, if specified, will be formatted according to its data type. If the content is itself of type `xml`, complex XML documents can be constructed. For example:

```
SELECT xmlelement(name foo, xmlattributes('xyz' as bar),
                            xmlelement(name abc),
                            xmlcomment('test'),
                            xmlelement(name xyz));

                 xmlelement
----------------------------------------------
 <foo bar="xyz"><abc/><!--test--><xyz/></foo>
```

Content of other types will be formatted into valid XML character data. This means in particular that the characters `<`, `>`, and `&` will be converted to entities. Binary data (data type `bytea`) will be represented in base64 or hex encoding, depending on the setting of the configuration parameter xmlbinary. The particular behavior for individual data types is expected to evolve in order to align the SQL and WarehousePG data types with the XML schema specification, at which point a more precise description will appear.

Function:

`xmlforest`

Synopsis:

```
xmlforest(<content> [AS <name>] [, ...])
```

The `xmlforest` expression produces an XML forest (sequence) of elements using the given names and content.

Examples:

```
SELECT xmlforest('abc' AS foo, 123 AS bar);

          xmlforest
------------------------------
 <foo>abc</foo><bar>123</bar>


SELECT xmlforest(table_name, column_name)
FROM information_schema.columns
WHERE table_schema = 'pg_catalog';

                                       xmlforest
----------------------------------------------------------------------------------------
 <table_name>pg_authid</table_name><column_name>rolname</column_name>
 <table_name>pg_authid</table_name><column_name>rolsuper</column_name>
```

As seen in the second example, the element name can be omitted if the content value is a column reference, in which case the column name is used by default. Otherwise, a name must be specified.

Element names that are not valid XML names are escaped as shown for `xmlelement` above. Similarly, content data is escaped to make valid XML content, unless it is already of type `xml`.

Note that XML forests are not valid XML documents if they consist of more than one element, so it might be useful to wrap `xmlforest` expressions in `xmlelement`.

Function:

`xmlpi`

Synopsis:

```
xmlpi(name <target> [, <content>])
```

The `xmlpi` expression creates an XML processing instruction. The content, if present, must not contain the character sequence `?>`.

Example:

```
SELECT xmlpi(name php, 'echo "hello world";');

            xmlpi
------------------------------
 <?php echo "hello world";?>
```

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Function:

`xmlroot`

Synopsis:

```
xmlroot(<xml>, version <text> | no value [, standalone yes|no|no value])
```

The `xmlroot` expression alters the properties of the root node of an XML value. If a version is specified, it replaces the value in the root node's version declaration; if a standalone setting is specified, it replaces the value in the root node's standalone declaration.

```
SELECT xmlroot(xmlparse(document '<?xml version="1.1"?><content>abc</content>'),
               version '1.0', standalone yes);

                xmlroot
----------------------------------------
 <?xml version="1.0" standalone="yes"?>
 <content>abc</content>
```

Function:

`xmlagg`

```
xmlagg (<xml>)
```

The function `xmlagg` is, unlike the other functions described here, an aggregate function. It concatenates the input values to the aggregate function call, much like `xmlconcat` does, except that concatenation occurs across rows rather than across expressions in a single row. See Using Functions and Operators for additional information about aggregate functions.

Example:

```
CREATE TABLE test (y int, x xml);
INSERT INTO test VALUES (1, '<foo>abc</foo>');
INSERT INTO test VALUES (2, '<bar/>');
SELECT xmlagg(x) FROM test;
        xmlagg
----------------------
 <foo>abc</foo><bar/>
```

To determine the order of the concatenation, an `ORDER BY` clause may be added to the aggregate call. For example:

```
SELECT xmlagg(x ORDER BY y DESC) FROM test;
        xmlagg
----------------------
 <bar/><foo>abc</foo>
```

The following non-standard approach used to be recommended in previous versions, and may still be useful in specific cases:

```
SELECT xmlagg(x) FROM (SELECT * FROM test ORDER BY y DESC) AS tab;
        xmlagg
----------------------
 <bar/><foo>abc</foo>
```

XML Predicates

The expressions described in this section check properties of `xml` values.

Expression:

`IS DOCUMENT`

Synopsis:

```
<xml> IS DOCUMENT
```

The expression `IS DOCUMENT` returns true if the argument XML value is a proper XML document, false if it is not (that is, it is a content fragment), or null if the argument is null.

Expression:

`XMLEXISTS`

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Synopsis:

```
XMLEXISTS(<text> PASSING [BY REF] <xml> [BY REF])
```

The function `xmlexists` returns true if the XPath expression in the first argument returns any nodes, and false otherwise. (If either argument is null, the result is null.)

Example:

```
SELECT xmlexists('//town[<text>() = ''Toronto'']' PASSING BY REF '<towns><town>Toronto</town><town>Ottawa</town></towns>');

 xmlexists
------------
 t
(1 row)
```

The `BY REF` clauses have no effect in WarehousePG, but are allowed for SQL conformance and compatibility with other implementations. Per SQL standard, the first `BY REF` is required, the second is optional. Also note that the SQL standard specifies the `xmlexists` construct to take an XQuery expression as first argument, but WarehousePG currently only supports XPath, which is a subset of XQuery.

Expression:

`xml_is_well_formed`

Synopsis:

```
xml_is_well_formed(<text>)
xml_is_well_formed_document(<text>)
xml_is_well_formed_content(<text>)
```

These functions check whether a text string is well-formed XML, returning a Boolean result. `xml_is_well_formed_document` checks for a well-formed document, while `xml_is_well_formed_content` checks for well-formed content. `xml_is_well_formed` does the former if the `xmloption` configuration parameter is set to `DOCUMENT`, or the latter if it is set to `CONTENT`. This means that `xml_is_well_formed` is useful for seeing whether a simple cast to type `xml` will succeed, whereas the other two functions are useful for seeing whether the corresponding variants of `XMLPARSE` will succeed.

Examples:

```
SET xmloption TO DOCUMENT;
SELECT xml_is_well_formed('<>');
 xml_is_well_formed
--------------------
 f
(1 row)

SELECT xml_is_well_formed('<abc/>');
 xml_is_well_formed
--------------------
 t
(1 row)

SET xmloption TO CONTENT;
SELECT xml_is_well_formed('abc');
 xml_is_well_formed
--------------------
 t
(1 row)

SELECT xml_is_well_formed_document('<pg:foo xmlns:pg="http://postgresql.org/stuff">bar</pg:foo>');
 xml_is_well_formed_document
-----------------------------
 t
(1 row)

SELECT xml_is_well_formed_document('<pg:foo xmlns:pg="http://postgresql.org/stuff">bar</my:foo>');
 xml_is_well_formed_document
-----------------------------
 f
(1 row)
```

The last example shows that the checks include whether namespaces are correctly matched.

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4.6.8 Using Full Text Search

WarehousePG provides data types, functions, operators, index types, and configurations for querying natural language documents.

- About Full Text Search
  This topic provides an overview of WarehousePG full text search, basic text search expressions, configuring, and customizing text search. WarehousePG full text search is compared with WarehousePG Text.
- Searching Text in Database Tables
  This topic shows how to use text search operators to search database tables and how to create indexes to speed up text searches.
- Controlling Text Search
  This topic shows how to create search and query vectors, how to rank search results, and how to highlight search terms in the results of text search queries.
- Additional Text Search Features
  WarehousePG has additional functions and operators you can use to manipulate search and query vectors, and to rewrite search queries.
- Text Search Parsers
  This topic describes the types of tokens the WarehousePG text search parser produces from raw text.
- Text Search Dictionaries
  Tokens produced by the WarehousePG full text search parser are passed through a chain of dictionaries to produce a normalized term or "lexeme". Different kinds of dictionaries are available to filter and transform tokens in different ways and for different languages.
- Text Search Configuration Example
  This topic shows how to create a customized text search configuration to process document and query text.
- Testing and Debugging Text Search
  This topic introduces the WarehousePG functions you can use to test and debug a search configuration or the individual parser and dictionaries specified in a configuration.
- GiST and GIN Indexes for Text Search
  This topic describes and compares the WarehousePG index types that are used for full text searching.
- psql Support
  The psql command-line utility provides a meta-command to display information about WarehousePG full text search configurations.
- Limitations
  This topic lists limitations and maximums for WarehousePG full text search objects.

Parent topic: Querying Data

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4.6.8.1 About Full Text Search

This topic provides an overview of WarehousePG full text search, basic text search expressions, configuring, and customizing text search. WarehousePG full text search is compared with WarehousePG Text.

This section contains the following subtopics:

- What is a Document?
- Basic Text Matching
- Configurations

Full Text Searching (or just "text search") provides the capability to identify natural-language *documents* that satisfy a *query*, and optionally to rank them by relevance to the query. The most common type of search is to find all documents containing given *query terms* and return them in order of their *similarity* to the query.

WarehousePG provides a data type `tsvector` to store preprocessed documents, and a data type `tsquery` to store processed queries (Text Search Data Types). There are many functions and operators available for these data types (Text Search Functions and Operators), the most important of which is the match operator `@@`, which we introduce in Basic Text Matching. Full text searches can be accelerated using indexes (GiST and GIN Indexes for Text Search).

Notions of query and similarity are very flexible and depend on the specific application. The simplest search considers query as a set of words and similarity as the frequency of query words in the document.

WarehousePG supports the standard text matching operators `~`, `~*`, `LIKE`, and `ILIKE` for textual data types, but these operators lack many essential properties required for searching documents:

- There is no linguistic support, even for English. Regular expressions are not sufficient because they cannot easily handle derived words, e.g., `satisfies` and `satisfy`. You might miss documents that contain `satisfies`, although you probably would like to find them when searching for `satisfy`. It is possible to use OR to search for multiple derived forms, but this is tedious and error-prone (some words can have several thousand derivatives).
- They provide no ordering (ranking) of search results, which makes them ineffective when thousands of matching documents are found.
- They tend to be slow because there is no index support, so they must process all documents for every search.

Full text indexing allows documents to be preprocessed and an index saved for later rapid searching. Preprocessing includes:

- **Parsing documents into tokens.** It is useful to identify various classes of tokens, e.g., numbers, words, complex words, email addresses, so that they can be processed differently. In principle token classes depend on the specific application, but for most purposes it is adequate to use a predefined set of classes. WarehousePG uses a *parser* to perform this step. A standard parser is provided, and custom parsers can be created for specific needs.
- **Converting tokens into lexemes.** A lexeme is a string, just like a token, but it has been *normalized* so that different forms of the same word are made alike. For example, normalization almost always includes folding upper-case letters to lower-case, and often involves removal of suffixes (such as s or es in English). This allows searches to find variant forms of the same word, without tediously entering all the possible variants. Also, this step typically eliminates *stop words*, which are words that are so common that they are useless for searching. (In short, then, tokens are raw fragments of the document text, while lexemes are words that are believed useful for indexing and searching.) WarehousePG uses *dictionaries* to perform this step. Various standard dictionaries are provided, and custom ones can be created for specific needs.
- **Storing preprocessed documents optimized for searching.** For example, each document can be represented as a sorted array of normalized lexemes. Along with the lexemes it is often desirable to store positional information to use for *proximity ranking*, so that a document that contains a more "dense" region of query words is assigned a higher rank than one with scattered query words.

Dictionaries allow fine-grained control over how tokens are normalized. With appropriate dictionaries, you can:

- Define stop words that should not be indexed.
- Map synonyms to a single word using Ispell.
- Map phrases to a single word using a thesaurus.
- Map different variations of a word to a canonical form using an Ispell dictionary.
- Map different variations of a word to a canonical form using Snowball stemmer rules.

What is a Document?

A *document* is the unit of searching in a full text search system; for example, a magazine article or email message. The text search engine must be able to parse documents and store associations of lexemes (key words) with their parent document. Later, these associations are used to search for documents that contain query words.

For searches within WarehousePG, a document is normally a textual field within a row of a database table, or possibly a combination (concatenation) of such fields, perhaps stored in several tables or obtained dynamically. In other words, a document can be constructed from different parts for indexing and it might not be stored anywhere as a whole. For example:

```
SELECT title || ' ' ||  author || ' ' ||  abstract || ' ' || body AS document
FROM messages
WHERE mid = 12;

SELECT m.title || ' ' || m.author || ' ' || m.abstract || ' ' || d.body AS document
FROM messages m, docs d
WHERE m.mid = d.did AND m.mid = 12;
```

> **Note** In these example queries, `coalesce` should be used to prevent a single `NULL` attribute from causing a `NULL` result for the whole document.

Another possibility is to store the documents as simple text files in the file system. In this case, the database can be used to store the full text index and to run searches, and some unique identifier can be used to retrieve the document from the file system. However, retrieving files from outside the database requires superuser permissions or special function support, so this is usually less convenient than keeping all the data inside WarehousePG. Also, keeping everything inside the database allows easy access to document metadata to assist in indexing and display.

For text search purposes, each document must be reduced to the preprocessed `tsvector` format. Searching and ranking are performed entirely on the tsvector representation of a document — the original text need only be retrieved when the document has been selected for display to a user. We therefore often speak of the `tsvector` as being the document, but of course it is only a compact representation of the full document.

Basic Text Matching

Full text searching in WarehousePG is based on the match operator `@@`, which returns `true` if a `tsvector` (document) matches a `tsquery` (query). It does not matter which data type is written first:

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```
SELECT 'a fat cat sat on a mat and ate a fat rat'::tsvector @@ 'cat & rat'::tsquery;
 ?column?
----------
 t

SELECT 'fat & cow'::tsquery @@ 'a fat cat sat on a mat and ate a fat rat'::tsvector;
 ?column?
----------
 f
```

As the above example suggests, a `tsquery` is not just raw text, any more than a `tsvector` is. A `tsquery` contains search terms, which must be already-normalized lexemes, and may combine multiple terms using AND, OR, NOT, and FOLLOWED BY operators. (For details see Text Search Data Types) There are functions `to_tsquery`, `plainto_tsquery`, and `phraseto_query` that are helpful in converting user-written text into a proper `tsquery`, for example by normalizing words appearing in the text. Similarly, `to_tsvector` is used to parse and normalize a document string. So in practice a text search match would look more like this:

```
SELECT to_tsvector('fat cats ate fat rats') @@ to_tsquery('fat & rat');
 ?column?
----------
 t
```

Observe that this match would not succeed if written as

```
SELECT 'fat cats ate fat rats'::tsvector @@ to_tsquery('fat & rat');
 ?column?
----------
 f
```

since here no normalization of the word `rats` will occur. The elements of a `tsvector` are lexemes, which are assumed already normalized, so `rats` does not match `rat`.

The `@@` operator also supports `text` input, allowing explicit conversion of a text string to `tsvector` or `tsquery` to be skipped in simple cases. The variants available are:

```
tsvector @@ tsquery
tsquery  @@ tsvector
text @@ tsquery
text @@ text
```

The first two of these we saw already. The form `text @@ tsquery` is equivalent to `to_tsvector(x) @@ y`. The form `text @@ text` is equivalent to `to_tsvector(x) @@ plainto_tsquery(y)`.

Within a `tsquery`, the `&` (AND) operator specifies that both its arguments must appear in the document to have a match. Similarly, the `|` (OR) operator specifies that at least one of its arguments must appear, while the `!` (NOT) operator specifies that its argument must *not* appear in order to have a match. For example, the query `fat & ! rat` matches documents that contain `fat` but not `rat`.

Searching for phrases is possible with the help of the `<->` (FOLLOWED BY) `tsquery` operator, which matches only if its arguments have matches that are adjacent and in the given order. For example:

```
SELECT to_tsvector('fatal error') @@ to_tsquery('fatal <-> error');
 ?column?
----------
 t

SELECT to_tsvector('error is not fatal') @@ to_tsquery('fatal <-> error');
 ?column?
----------
 f
```

There is a more general version of the FOLLOWED BY operator having the form `<N>`, where *N* is an integer standing for the difference between the positions of the matching lexemes. `<1>` is the same as `<->`, while `<2>` allows exactly one other lexeme to appear between the matches, and so on. The `phraseto_tsquery` function makes use of this operator to construct a `tsquery` that can match a multi-word phrase when some of the words are stop words. For example:

```
SELECT phraseto_tsquery('cats ate rats');
       phraseto_tsquery
-------------------------------
 'cat' <-> 'ate' <-> 'rat'

SELECT phraseto_tsquery('the cats ate the rats');
       phraseto_tsquery
-------------------------------
 'cat' <-> 'ate' <2> 'rat'
```

A special case that's sometimes useful is that `<0>` can be used to require that two patterns match the same word.

Parentheses can be used to control nesting of the tsquery operators. Without parentheses, `|` binds least tightly, then `&`, then `<->`, and `!` most tightly.

It's worth noticing that the AND/OR/NOT operators mean something subtly different when they are within the arguments of a FOLLOWED BY operator than when they are not, because within FOLLOWED BY the exact position of the match is significant. For example, normally `!x` matches only documents that do not contain `x` anywhere. But `!x <-> y` matches `y` if it is not immediately after an `x`; an occurrence of `x` elsewhere in the document does not prevent a match. Another example is that `x & y` normally only requires that `x` and `y` both appear somewhere in the document, but `(x & y) <-> z` requires `x` and `y` to match at the same place, immediately before a `z`. Thus this query behaves differently from `x <-> z & y <-> z`, which will match a document containing two separate sequences `x z` and `y z`. (This specific query is useless as written, since `x` and `y` could not match at the same place; but with more complex situations such as prefix-match patterns, a query of this form could be useful.)

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Configurations

The above are all simple text search examples. As mentioned before, full text search functionality includes the ability to do many more things: skip indexing certain words (stop words), process synonyms, and use sophisticated parsing, e.g., parse based on more than just white space. This functionality is controlled by *text search configurations*. WarehousePG comes with predefined configurations for many languages, and you can easily create your own configurations. (psql's `\dF` command shows all available configurations.)

During installation an appropriate configuration is selected and default_text_search_config is set accordingly in `postgresql.conf`. If you are using the same text search configuration for the entire cluster you can use the value in `postgresql.conf`. To use different configurations throughout the cluster but the same configuration within any one database, use `ALTER DATABASE ... SET`. Otherwise, you can set `default_text_search_config` in each session.

Each text search function that depends on a configuration has an optional `regconfig` argument, so that the configuration to use can be specified explicitly. `default_text_search_config` is used only when this argument is omitted.

To make it easier to build custom text search configurations, a configuration is built up from simpler database objects. WarehousePG's text search facility provides four types of configuration-related database objects:

- *Text search parsers* break documents into tokens and classify each token (for example, as words or numbers).
- *Text search dictionaries* convert tokens to normalized form and reject stop words.
- *Text search templates* provide the functions underlying dictionaries. (A dictionary simply specifies a template and a set of parameters for the template.)
- *Text search configurations* select a parser and a set of dictionaries to use to normalize the tokens produced by the parser.

Text search parsers and templates are built from low-level C functions; therefore it requires C programming ability to develop new ones, and superuser privileges to install one into a database. (There are examples of add-on parsers and templates in the `contrib/` area of the WarehousePG distribution.) Since dictionaries and configurations just parameterize and connect together some underlying parsers and templates, no special privilege is needed to create a new dictionary or configuration. Examples of creating custom dictionaries and configurations appear later in this chapter.

Parent topic: Using Full Text Search

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4.6.8.2 Searching Text in Database Tables

This topic shows how to use text search operators to search database tables and how to create indexes to speed up text searches.

The examples in the previous section illustrated full text matching using simple constant strings. This section shows how to search table data, optionally using indexes.

This section contains the following subtopics:

- Searching a Table
- Creating Indexes

Searching a Table

It is possible to do a full text search without an index. A simple query to print the `title` of each row that contains the word `friend` in its `body` field is:

```
SELECT title
FROM pgweb
WHERE to_tsvector('english', body) @@ to_tsquery('english', 'friend');
```

This will also find related words such as `friends` and `friendly`, since all these are reduced to the same normalized lexeme.

The query above specifies that the `english` configuration is to be used to parse and normalize the strings. Alternatively we could omit the configuration parameters:

```
SELECT title
FROM pgweb
WHERE to_tsvector(body) @@ to_tsquery('friend');
```

This query will use the configuration set by default_text_search_config.

A more complex example is to select the ten most recent documents that contain `create` and `table` in the `title` or `body`:

```
SELECT title
FROM pgweb
WHERE to_tsvector(title || ' ' || body) @@ to_tsquery('create & table')
ORDER BY last_mod_date DESC
LIMIT 10;
```

For clarity we omitted the `coalesce` function calls which would be needed to find rows that contain `NULL` in one of the two fields.

Although these queries will work without an index, most applications will find this approach too slow, except perhaps for occasional ad-hoc searches. Practical use of text searching usually requires creating an index.

Creating Indexes

We can create a GIN index (GiST and GIN Indexes for Text Search) to speed up text searches:

```
CREATE INDEX pgweb_idx ON pgweb USING GIN (to_tsvector('english', body));
```

Notice that the two-argument version of `to_tsvector` is used. Only text search functions that specify a configuration name can be used in expression indexes. This is because the index contents must be unaffected by default_text_search_config. If they were affected, the index contents might be inconsistent because different entries could contain `tsvector`s that were created with different text search configurations, and there would be no way to guess which was which. It would be impossible to dump and restore such an index correctly.

Because the two-argument version of `to_tsvector` was used in the index above, only a query reference that uses the two-argument version of `to_tsvector` with the same configuration name will use that index. That is, `WHERE to_tsvector('english', body) @@ 'a & b'` can use the index, but `WHERE to_tsvector(body) @@ 'a & b'` cannot. This ensures that an index will be used only with the same configuration used to create the index entries.

It is possible to set up more complex expression indexes wherein the configuration name is specified by another column, e.g.:

```
CREATE INDEX pgweb_idx ON pgweb USING GIN (to_tsvector(config_name, body));
```

where `config_name` is a column in the `pgweb` table. This allows mixed configurations in the same index while recording which configuration was used for each index entry. This would be useful, for example, if the document collection contained documents in different languages. Again, queries that are meant to use the index must be phrased to match, e.g., `WHERE to_tsvector(config_name, body) @@ 'a & b'`.

Indexes can even concatenate columns:

```
CREATE INDEX pgweb_idx ON pgweb USING GIN (to_tsvector('english', title || ' ' || body));
```

Another approach is to create a separate `tsvector` column to hold the output of `to_tsvector`. To keep this column automatically up to date with its source data, use a stored generated column. This example is a concatenation of title and body, using `coalesce` to ensure that one field will still be indexed when the other is NULL:

```
ALTER TABLE pgweb
    ADD COLUMN textsearchable_index_col tsvector
        GENERATED ALWAYS AS (to_tsvector('english', coalesce(title, '') || ' ' || coalesce(body, ''))) STORED;
```

Then we create a GIN index to speed up the search:

```
CREATE INDEX textsearch_idx ON pgweb USING GIN (textsearchable_index_col);
```

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Now we are ready to perform a fast full text search:

```
SELECT title FROM pgweb WHERE textsearchable_index_col @@ to_tsquery('create & table')
ORDER BY last_mod_date DESC LIMIT 10;
```

One advantage of the separate-column approach over an expression index is that it is not necessary to explicitly specify the text search configuration in queries in order to make use of the index. As shown in the example above, the query can depend on `default_text_search_config`. Another advantage is that searches will be faster, since it will not be necessary to redo the `to_tsvector` calls to verify index matches. (This is more important when using a GiST index than a GIN index; see GiST and GIN Indexes for Text Search.) The expression-index approach is simpler to set up, however, and it requires less disk space since the `tsvector` representation is not stored explicitly.

Parent topic: Using Full Text Search

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4.6.8.3 Controlling Text Search

This topic shows how to create search and query vectors, how to rank search results, and how to highlight search terms in the results of text search queries.

To implement full text searching there must be a function to create a `tsvector` from a document and a `tsquery` from a user query. Also, we need to return results in a useful order, so we need a function that compares documents with respect to their relevance to the query. It's also important to be able to display the results nicely. WarehousePG provides support for all of these functions.

This topic contains the following subtopics:

- Parsing Documents
- Parsing Queries
- Ranking Search Results
- Highlighting Results

Parsing Documents

WarehousePG provides the function `to_tsvector` for converting a document to the `tsvector` data type.

```
to_tsvector([<config> regconfig, ] <document> text) returns tsvector
```

`to_tsvector` parses a textual document into tokens, reduces the tokens to lexemes, and returns a `tsvector` which lists the lexemes together with their positions in the document. The document is processed according to the specified or default text search configuration. Here is a simple example:

```
SELECT to_tsvector('english', 'a fat  cat sat on a mat - it ate a fat rats');
                  to_tsvector
-----------------------------------------------------
 'ate':9 'cat':3 'fat':2,11 'mat':7 'rat':12 'sat':4
```

In the example above we see that the resulting tsvector does not contain the words `a`, `on`, or `it`, the word `rats` became `rat`, and the punctuation sign `-` was ignored.

The `to_tsvector` function internally calls a parser which breaks the document text into tokens and assigns a type to each token. For each token, a list of dictionaries (Text Search Dictionaries) is consulted, where the list can vary depending on the token type. The first dictionary that *recognizes* the token emits one or more normalized *lexemes* to represent the token. For example, `rats` became `rat` because one of the dictionaries recognized that the word `rats` is a plural form of `rat`. Some words are recognized as *stop words*, which causes them to be ignored since they occur too frequently to be useful in searching. In our example these are `a`, `on`, and `it`. If no dictionary in the list recognizes the token then it is also ignored. In this example that happened to the punctuation sign `-` because there are in fact no dictionaries assigned for its token type (`Space symbols`), meaning space tokens will never be indexed. The choices of parser, dictionaries and which types of tokens to index are determined by the selected text search configuration (Text Search Configuration Example). It is possible to have many different configurations in the same database, and predefined configurations are available for various languages. In our example we used the default configuration `english` for the English language.

The function `setweight` can be used to label the entries of a `tsvector` with a given *weight*, where a weight is one of the letters `A`, `B`, `C`, or `D`. This is typically used to mark entries coming from different parts of a document, such as `title` versus `body`. Later, this information can be used for ranking of search results.

Because `to_tsvector(NULL)` will return `NULL`, it is recommended to use `coalesce` whenever a field might be null. Here is the recommended method for creating a tsvector from a structured document:

```
UPDATE tt SET ti = setweight(to_tsvector(coalesce(title,'')), 'A')
  || setweight(to_tsvector(coalesce(keyword,'')), 'B')
  || setweight(to_tsvector(coalesce(abstract,'')), 'C')
  || setweight(to_tsvector(coalesce(body,'')), 'D');
```

Here we have used `setweight` to label the source of each lexeme in the finished `tsvector`, and then merged the labeled `tsvector` values using the `tsvector` concatenation operator `||`. (Additional Text Search Features gives details about these operations.)

Parsing Queries

WarehousePG provides the functions `to_tsquery`, `plainto_tsquery`, `phraseto_tsquery`, and `websearch_to_tsquery` for converting a query to the `tsquery` data type. `to_tsquery` offers access to more features than `plainto_tsquery`, but is less forgiving about its input. `websearch_to_tsquery` is a simplified version of `to_tsquery` with an alternative syntax, similar to the one used by web search engines.

```
to_tsquery([<config> regconfig, ] <querytext> text) returns tsquery
```

`to_tsquery` creates a `tsquery` value from *querytext*, which must consist of single tokens separated by the Boolean operators `&` (AND), `|` (OR), `!` (NOT), and <-> (FOLLOWED BY), possibly grouped using parentheses. In other words, the input to `to_tsquery` must already follow the general rules for tsquery input, as described in Text Search Data Types. The difference is that while basic `tsquery` input takes the tokens at face value, `to_tsquery` normalizes each token to a lexeme using the specified or default configuration, and discards any tokens that are stop words according to the configuration. For example:

```
SELECT to_tsquery('english', 'The & Fat & Rats');
  to_tsquery
---------------
 'fat' & 'rat'
```

As in basic `tsquery` input, weight(s) can be attached to each lexeme to restrict it to match only `tsvector` lexemes of those weight(s). For example:

```
SELECT to_tsquery('english', 'Fat | Rats:AB');
    to_tsquery
------------------
 'fat' | 'rat':AB
```

Also, `*` can be attached to a lexeme to specify prefix matching:

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```
SELECT to_tsquery('supern:*A & star:A*B');
        to_tsquery
--------------------------
 'supern':*A & 'star':*AB
```

Such a lexeme will match any word in a `tsvector` that begins with the given string.

`to_tsquery` can also accept single-quoted phrases. This is primarily useful when the configuration includes a thesaurus dictionary that may trigger on such phrases. In the example below, a thesaurus contains the rule `supernovae stars : sn`:

```
SELECT to_tsquery('''supernovae stars'' & !crab');
  to_tsquery
---------------
 'sn' & !'crab'
```

Without quotes, `to_tsquery` will generate a syntax error for tokens that are not separated by an AND, OR, or FOLLOWED BY operator.

```
plainto_tsquery([ <config> regconfig, ] <querytext> ext) returns tsquery
```

`plainto_tsquery` transforms unformatted text `*querytext*` to `tsquery`. The text is parsed and normalized much as for `to_tsvector`, then the `&` (AND) Boolean operator is inserted between surviving words.

Example:

```
SELECT plainto_tsquery('english', 'The Fat Rats');
 plainto_tsquery
-----------------
 'fat' & 'rat'
```

Note that `plainto_tsquery` cannot recognize Boolean operators, weight labels, or prefix-match labels in its input:

```
SELECT plainto_tsquery('english', 'The Fat & Rats:C');
   plainto_tsquery
----------------------
 'fat' & 'rat' & 'c'
```

Here, all the input punctuation was discarded as being space symbols.

```
phraseto_tsquery([ <config> regconfig, ] <querytext> text) returns tsquery
```

`phraseto_tsquery` behaves much like `plainto_tsquery`, except that it inserts the `<->` (FOLLOWED BY) operator between surviving words instead of the `&` (AND) operator. Also, stop words are not simply discarded, but are accounted for by inserting `<N>` operators rather than `<->` operators. This function is useful when searching for exact lexeme sequences, since the FOLLOWED BY operators check lexeme order not just the presence of all the lexemes.

Example:

```
SELECT phraseto_tsquery('english', 'The Fat Rats');
 phraseto_tsquery
------------------
 'fat' <-> 'rat'
```

Like `plainto_tsquery`, the `phraseto_tsquery` function will not recognize `tsquery` operators, weight labels, or prefix-match labels in its input:

```
SELECT phraseto_tsquery('english', 'The Fat & Rats:C');
      phraseto_tsquery
-----------------------------
 'fat' <-> 'rat' <-> 'c'
```

```
websearch_to_tsquery([ <config> regconfig, ] <querytext> text) returns tsquery
```

`websearch_to_tsquery` creates a `tsquery` value from querytext using an alternative syntax in which simple unformatted text is a valid query. Unlike `plainto_tsquery` and `phraseto_tsquery`, it also recognizes certain operators. Moreover, this function should never raise syntax errors, which makes it possible to use raw user-supplied input for search. The following syntax is supported:

- `unquoted text`: text not inside quote marks will be converted to terms separated by `&` operators, as if processed by `plainto_tsquery`.
- `"quoted text"`: text inside quote marks will be converted to terms separated by `<->` operators, as if processed by `phraseto_tsquery`.
- `OR`: logical or will be converted to the `|` operator.
- `-`: the logical not operator, converted to the `!` operator.

Examples:

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```
SELECT websearch_to_tsquery('english', 'The fat rats');
 websearch_to_tsquery
----------------------
 'fat' & 'rat'
(1 row)

SELECT websearch_to_tsquery('english', '"supernovae stars" -crab');
       websearch_to_tsquery
---------------------------------
 'supernova' <-> 'star' & !'crab'
(1 row)

SELECT websearch_to_tsquery('english', '"sad cat" or "fat rat"');
       websearch_to_tsquery
-----------------------------------
 'sad' <-> 'cat' | 'fat' <-> 'rat'
(1 row)

SELECT websearch_to_tsquery('english', 'signal -"segmentation fault"');
         websearch_to_tsquery
---------------------------------------
 'signal' & !( 'segment' <-> 'fault' )
(1 row)

SELECT websearch_to_tsquery('english', '""" )( dummy \\ query <->');
 websearch_to_tsquery
----------------------
 'dummi' & 'queri'
(1 row)
```

Ranking Search Results

Ranking attempts to measure how relevant documents are to a particular query, so that when there are many matches the most relevant ones can be shown first. WarehousePG provides two predefined ranking functions, which take into account lexical, proximity, and structural information; that is, they consider how often the query terms appear in the document, how close together the terms are in the document, and how important is the part of the document where they occur. However, the concept of relevancy is vague and very application-specific. Different applications might require additional information for ranking, e.g., document modification time. The built-in ranking functions are only examples. You can write your own ranking functions and/or combine their results with additional factors to fit your specific needs.

The two ranking functions currently available are:

`ts_rank([ <weights> float4[], ] <vector> tsvector, <query> tsquery [, <normalization> integer ]) returns float4` Ranks vectors based on the frequency of their matching lexemes.

`ts_rank_cd([ <weights> float4[], ] <vector> tsvector, <query> tsquery [, <normalization> integer ]) returns float4` This function computes the *cover density* ranking for the given document vector and query, as described in Clarke, Cormack, and Tudhope's "Relevance Ranking for One to Three Term Queries" in the journal "Information Processing and Management", 1999. Cover density is similar to `ts_rank` ranking except that the proximity of matching lexemes to each other is taken into consideration.

This function requires lexeme positional information to perform its calculation. Therefore, it ignores any "stripped" lexemes in the `tsvector`. If there are no unstripped lexemes in the input, the result will be zero. (See Manipulating Documents for more information about the `strip` function and positional information in `tsvector` s.)

For both these functions, the optional `<weights>` argument offers the ability to weigh word instances more or less heavily depending on how they are labeled. The weight arrays specify how heavily to weigh each category of word, in the order:

```
{D-weight, C-weight, B-weight, A-weight}
```

If no `<weights>` are provided, then these defaults are used:

```
{0.1, 0.2, 0.4, 1.0}
```

Typically weights are used to mark words from special areas of the document, like the title or an initial abstract, so they can be treated with more or less importance than words in the document body.

Since a longer document has a greater chance of containing a query term it is reasonable to take into account document size, e.g., a hundred-word document with five instances of a search word is probably more relevant than a thousand-word document with five instances. Both ranking functions take an integer `<normalization>` option that specifies whether and how a document's length should impact its rank. The integer option controls several behaviors, so it is a bit mask: you can specify one or more behaviors using `|` (for example, `2|4`).

- 0 (the default) ignores the document length
- 1 divides the rank by 1 + the logarithm of the document length
- 2 divides the rank by the document length
- 4 divides the rank by the mean harmonic distance between extents (this is implemented only by `ts_rank_cd`)
- 8 divides the rank by the number of unique words in document
- 16 divides the rank by 1 + the logarithm of the number of unique words in document
- 32 divides the rank by itself + 1

If more than one flag bit is specified, the transformations are applied in the order listed.

It is important to note that the ranking functions do not use any global information, so it is impossible to produce a fair normalization to 1% or 100% as sometimes desired. Normalization option `32 (rank/(rank+1))` can be applied to scale all ranks into the range zero to one, but of course this is just a cosmetic change; it will not affect the ordering of the search results.

Here is an example that selects only the ten highest-ranked matches:

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```
SELECT title, ts_rank_cd(textsearch, query) AS rank
FROM apod, to_tsquery('neutrino|(dark & matter)') query
WHERE query @@ textsearch
ORDER BY rank DESC
LIMIT 10;
                     title                     |   rank
-----------------------------------------------+----------
 Neutrinos in the Sun                          |      3.1
 The Sudbury Neutrino Detector                 |      2.4
 A MACHO View of Galactic Dark Matter          |  2.01317
 Hot Gas and Dark Matter                       |  1.91171
 The Virgo Cluster: Hot Plasma and Dark Matter |  1.90953
 Rafting for Solar Neutrinos                   |      1.9
 NGC 4650A: Strange Galaxy and Dark Matter     |  1.85774
 Hot Gas and Dark Matter                       |   1.6123
 Ice Fishing for Cosmic Neutrinos              |      1.6
 Weak Lensing Distorts the Universe            | 0.818218
```

This is the same example using normalized ranking:

```
SELECT title, ts_rank_cd(textsearch, query, 32 /* rank/(rank+1) */ ) AS rank
FROM apod, to_tsquery('neutrino|(dark & matter)') query
WHERE  query @@ textsearch
ORDER BY rank DESC
LIMIT 10;
                     title                     |        rank
-----------------------------------------------+-------------------
 Neutrinos in the Sun                          | 0.756097569485493
 The Sudbury Neutrino Detector                 | 0.705882361190954
 A MACHO View of Galactic Dark Matter          | 0.668123210574724
 Hot Gas and Dark Matter                       |  0.65655958650282
 The Virgo Cluster: Hot Plasma and Dark Matter | 0.656301290640973
 Rafting for Solar Neutrinos                   | 0.655172410958162
 NGC 4650A: Strange Galaxy and Dark Matter     | 0.650072921219637
 Hot Gas and Dark Matter                       | 0.617195790024749
 Ice Fishing for Cosmic Neutrinos              | 0.615384618911517
 Weak Lensing Distorts the Universe            | 0.450010798361481
```

Ranking can be expensive since it requires consulting the tsvector of each matching document, which can be I/O bound and therefore slow. Unfortunately, it is almost impossible to avoid since practical queries often result in large numbers of matches.

Highlighting Results

To present search results it is ideal to show a part of each document and how it is related to the query. Usually, search engines show fragments of the document with marked search terms. WarehousePG provides a function `ts_headline` that implements this functionality.

```
ts_headline([<config> regconfig, ] <document> text, <query> tsquery [, <options> text ]) returns text
```

`ts_headline` accepts a document along with a query, and returns an excerpt from the document in which terms from the query are highlighted. The configuration to be used to parse the document can be specified by `*config*`; if `*config*` is omitted, the `default_text_search_config` configuration is used.

If an `*options*` string is specified it must consist of a comma-separated list of one or more `*option=value*` pairs. The available options are:

- `MaxWords`, `MinWords` (integers): these numbers determine the longest and shortest headlines to output. The default values are 35 and 15.
- `ShortWord` (integer): words of this length or less will be dropped at the start and end of a headline, unless they are query terms. The default value of three eliminates common English articles.
- `HighlightAll` (boolean): the whole document will be used as the headline, ignoring the preceding three parameters. The default is `false`.
- `MaxFragments` (integer): maximum number of text fragments to display. The default value of zero selects a non-fragment-based headline generation method. A value greater than zero selects fragment-based headline generation (see below).
- `StartSel`, `StopSel` (strings): the strings with which to delimit query words appearing in the document, to distinguish them from other excerpted words. The default values are `<b>` " and " `</b>` ", which can be suitable for HTML output.
- `FragmentDelimiter` (string): When more than one fragment is displayed, the fragments will be separated by this string. The default is " `...` ".

These option names are recognized case-insensitively. You must double-quote string values if they contain spaces or commas.

In non-fragment-based headline generation, `ts_headline` locates matches for the given `<query>` and chooses a single one to display, preferring matches that have more query words within the allowed headline length. In fragment-based headline generation, `ts_headline` locates the query matches and splits each match into “fragments” of no more than `MaxWords` words each, preferring fragments with more query words, and when possible “stretching” fragments to include surrounding words. The fragment-based mode is thus more useful when the query matches span large sections of the document, or when it’s desirable to display multiple matches. In either mode, if no query matches can be identified, then a single fragment of the first `MinWords` words in the document will be displayed.

For example:

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```
SELECT ts_headline('english',
  'The most common type of search
is to find all documents containing given query terms
and return them in order of their similarity to the
query.',
  to_tsquery('english', 'query & similarity'));
                        ts_headline
------------------------------------------------------------
 containing given <b>query</b> terms                       +
 and return them in order of their <b>similarity</b> to the+
 <b>query</b>.

SELECT ts_headline('english',
  'Search terms may occur
many times in a document,
requiring ranking of the search matches to decide which
occurrences to display in the result.',
  to_tsquery('english', 'search & term'),
  'MaxFragments=10, MaxWords=7, MinWords=3, StartSel=<<, StopSel=>>');
                        ts_headline
------------------------------------------------------------
 <<Search>> <<terms>> may occur                            +
 many times ... ranking of the <<search>> matches to decide
```

`ts_headline` uses the original document, not a `tsvector` summary, so it can be slow and should be used with care.

Parent topic: Using Full Text Search

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4.6.8.4 Additional Text Search Features

WarehousePG has additional functions and operators you can use to manipulate search and query vectors, and to rewrite search queries.

This section contains the following subtopics:

- Manipulating Documents
- Manipulating Queries
- Rewriting Queries
- Gathering Document Statistics

Manipulating Documents

Parsing Documents showed how raw textual documents can be converted into `tsvector` values. WarehousePG also provides functions and operators that can be used to manipulate documents that are already in `tsvector` form.

`tsvector || tsvector` The `tsvector` concatenation operator returns a vector which combines the lexemes and positional information of the two vectors given as arguments. Positions and weight labels are retained during the concatenation. Positions appearing in the right-hand vector are offset by the largest position mentioned in the left-hand vector, so that the result is nearly equivalent to the result of performing `to_tsvector` on the concatenation of the two original document strings. (The equivalence is not exact, because any stop-words removed from the end of the left-hand argument will not affect the result, whereas they would have affected the positions of the lexemes in the right-hand argument if textual concatenation were used.)

One advantage of using concatenation in the vector form, rather than concatenating text before applying `to_tsvector`, is that you can use different configurations to parse different sections of the document. Also, because the `setweight` function marks all lexemes of the given vector the same way, it is necessary to parse the text and do `setweight` before concatenating if you want to label different parts of the document with different weights.

`setweight(<vector> tsvector, <weight> "char") returns tsvector` `setweight` returns a copy of the input vector in which every position has been labeled with the given `<weight>`, either `A`, `B`, `C`, or `D`. (`D` is the default for new vectors and as such is not displayed on output.) These labels are retained when vectors are concatenated, allowing words from different parts of a document to be weighted differently by ranking functions.

Note that weight labels apply to **positions**, not **lexemes**. If the input vector has been stripped of positions then `setweight` does nothing.

`length(<vector> tsvector) returns integer` Returns the number of lexemes stored in the vector.

`strip(vector tsvector) returns tsvector` Returns a vector that lists the same lexemes as the given vector, but lacks any position or weight information. The result is usually much smaller than an unstripped vector, but it is also less useful. Relevance ranking does not work as well on stripped vectors as unstripped ones. Also, the `<->` (FOLLOWED BY) `tsquery` operator will never match stripped input, since it cannot determine the distance between lexeme occurrences.

A full list of tsvector-related functions is available in Text Search Functions and Operators in the PostgreSQL documentation.

Manipulating Queries

Parsing Queries showed how raw textual queries can be converted into `tsquery` values. WarehousePG also provides functions and operators that can be used to manipulate queries that are already in `tsquery` form.

`tsquery && tsquery` Returns the AND-combination of the two given queries.

`tsquery || tsquery` Returns the OR-combination of the two given queries.

`!! tsquery` Returns the negation (NOT) of the given query.

`tsquery <-> tsquery` Returns a query that searches for a match to the first given query immediately followed by a match to the second given query, using the `<->` (FOLLOWED BY) `tsquery` operator. For example:

```
SELECT to_tsquery('fat') <-> to_tsquery('cat | rat');
          ?column?
----------------------------
 'fat' <-> ( 'cat' | 'rat' )
```

`tsquery_phrase(<query1> tsquery, <query2> tsquery [, <distance> integer ]) returns tsquery` Returns a query that searches for a match to the first given query followed by a match to the second given query at a distance of exactly `<distance>` lexemes, using the `<N>` `tsquery` operator. For example:

```
SELECT tsquery_phrase(to_tsquery('fat'), to_tsquery('cat'), 10);
  tsquery_phrase
------------------
 'fat' <10> 'cat'
```

`numnode(<query> tsquery) returns integer` Returns the number of nodes (lexemes plus operators) in a tsquery. This function is useful to determine if the **query** is meaningful (returns > 0), or contains only stop words (returns 0). Examples:

```
SELECT numnode(plainto_tsquery('the any'));
NOTICE:  query contains only stopword(s) or doesn't contain lexeme(s), ignored
 numnode
---------
       0

SELECT numnode('foo & bar'::tsquery);
 numnode
---------
       3
```

`querytree(<query> tsquery) returns text` Returns the portion of a tsquery that can be used for searching an index. This function is useful for detecting unindexable queries, for example those containing only stop words or only negated terms. For example:

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```
SELECT querytree(to_tsquery('!defined'));
 querytree
-----------
```

Rewriting Queries

The `ts_rewrite` family of functions search a given `tsquery` for occurrences of a target subquery, and replace each occurrence with a substitute subquery. In essence this operation is a `tsquery`-specific version of substring replacement. A target and substitute combination can be thought of as a *query rewrite rule*. A collection of such rewrite rules can be a powerful search aid. For example, you can expand the search using synonyms (e.g. `new york`, `big apple`, `nyc`, `gotham`) or narrow the search to direct the user to some hot topic. There is some overlap in functionality between this feature and thesaurus dictionaries (Thesaurus Dictionary). However, you can modify a set of rewrite rules on-the-fly without reindexing, whereas updating a thesaurus requires reindexing to be effective.

`ts_rewrite(<query> tsquery, <target> tsquery, <substitute> tsquery) returns tsquery` This form of `ts_rewrite` simply applies a single rewrite rule: `<target>` is replaced by `<substitute>` wherever it appears in `<query>`. For example:

```
SELECT ts_rewrite('a & b'::tsquery, 'a'::tsquery, 'c'::tsquery);
 ts_rewrite
------------
 'b' & 'c'
```

`ts_rewrite(<query> tsquery, <select> text) returns tsquery` This form of `ts_rewrite` accepts a starting `<query>` and a SQL `<select>` command, which is given as a text string. The `<select>` must yield two columns of `tsquery` type. For each row of the `<select>` result, occurrences of the first column value (the target) are replaced by the second column value (the substitute) within the current `<query>` value. For example:

```
CREATE TABLE aliases (id int, t tsquery, s tsquery);
INSERT INTO aliases VALUES(1, 'a', 'c');

SELECT ts_rewrite('a & b'::tsquery, 'SELECT t,s FROM aliases');
 ts_rewrite
------------
 'b' & 'c'
```

Note that when multiple rewrite rules are applied in this way, the order of application can be important; so in practice you will want the source query to `ORDER BY` some ordering key.

Let's consider a real-life astronomical example. We'll expand query `supernovae` using table-driven rewriting rules:

```
CREATE TABLE aliases (id int, t tsquery primary key, s tsquery);
INSERT INTO aliases VALUES(1, to_tsquery('supernovae'), to_tsquery('supernovae|sn'));

SELECT ts_rewrite(to_tsquery('supernovae & crab'), 'SELECT t, s FROM aliases');
           ts_rewrite
---------------------------------
 'crab' & ( 'supernova' | 'sn' )
```

We can change the rewriting rules just by updating the table:

```
UPDATE aliases
SET s = to_tsquery('supernovae|sn & !nebulae')
WHERE t = to_tsquery('supernovae');

SELECT ts_rewrite(to_tsquery('supernovae & crab'), 'SELECT t, s FROM aliases');
                 ts_rewrite
---------------------------------------------
 'crab' & ( 'supernova' | 'sn' & !'nebula' )
```

Rewriting can be slow when there are many rewriting rules, since it checks every rule for a possible match. To filter out obvious non-candidate rules we can use the containment operators for the `tsquery` type. In the example below, we select only those rules which might match the original query:

```
SELECT ts_rewrite('a & b'::tsquery,
                  'SELECT t,s FROM aliases WHERE ''a & b''::tsquery @> t');
 ts_rewrite
------------
 'b' & 'c'
```

Gathering Document Statistics

The function `ts_stat` is useful for checking your configuration and for finding stop-word candidates.

```
ts_stat(<sqlquery> text, [ <weights> text, ]
        OUT <word> text, OUT <ndoc> integer,
        OUT <nentry> integer) returns setof record
```

`<sqlquery>` is a text value containing an SQL query which must return a single `tsvector` column. `ts_stat` runs the query and returns statistics about each distinct lexeme (word) contained in the `tsvector` data. The columns returned are

- `<word> text` — the value of a lexeme
- `<ndoc> integer` — number of documents (`tsvector`s) the word occurred in
- `<nentry> integer` — total number of occurrences of the word

If weights is supplied, only occurrences having one of those weights are counted.

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For example, to find the ten most frequent words in a document collection:

```
SELECT * FROM ts_stat('SELECT vector FROM apod')
ORDER BY nentry DESC, ndoc DESC, word
LIMIT 10;
```

The same, but counting only word occurrences with weight `A` or `B`:

```
SELECT * FROM ts_stat('SELECT vector FROM apod', 'ab')
ORDER BY nentry DESC, ndoc DESC, word
LIMIT 10;
```

Parent topic: Using Full Text Search

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4.6.8.5 Text Search Parsers

This topic describes the types of tokens the WarehousePG text search parser produces from raw text.

Text search parsers are responsible for splitting raw document text into *tokens* and identifying each token's type, where the set of possible types is defined by the parser itself. Note that a parser does not modify the text at all — it simply identifies plausible word boundaries. Because of this limited scope, there is less need for application-specific custom parsers than there is for custom dictionaries. At present WarehousePG provides just one built-in parser, which has been found to be useful for a wide range of applications.

The built-in parser is named `pg_catalog.default`. It recognizes 23 token types, shown in the following table.

Alias	Description	Example
asciiword	Word, all ASCII letters	elephant
word	Word, all letters	mañana
numword	Word, letters and digits	beta1
asciihword	Hyphenated word, all ASCII	up-to-date
hword	Hyphenated word, all letters	lógico-matemática
numhword	Hyphenated word, letters and digits	postgresql-beta1
hword_asciipart	Hyphenated word part, all ASCII	postgresql in the context postgresql-beta1
hword_part	Hyphenated word part, all letters	lógico or matemática in the context lógico-matemática
hword_numpart	Hyphenated word part, letters and digits	beta1 in the context postgresql-beta1
email	Email address	foo@example.com
protocol	Protocol head	http\://
url	URL	example.com/stuff/index.html
host	Host	example.com
url_path	URL path	/stuff/index.html, in the context of a URL
file	File or path name	/usr/local/foo.txt, if not within a URL
sfloat	Scientific notation	-1.234e56
float	Decimal notation	-1.234
int	Signed integer	-1234
uint	Unsigned integer	1234
version	Version number	8.3.0
tag	XML tag	\<a href="dictionaries.html">
entity	XML entity	\&
blank	Space symbols	(any whitespace or punctuation not otherwise recognized)

> **Note** The parser's notion of a "letter" is determined by the database's locale setting, specifically `lc_ctype`. Words containing only the basic ASCII letters are reported as a separate token type, since it is sometimes useful to distinguish them. In most European languages, token types `word` and `asciiword` should be treated alike.

`email` does not support all valid email characters as defined by RFC 5322. Specifically, the only non-alphanumeric characters supported for email user names are period, dash, and underscore.

It is possible for the parser to produce overlapping tokens from the same piece of text. As an example, a hyphenated word will be reported both as the entire word and as each component:

```
SELECT alias, description, token FROM ts_debug('foo-bar-beta1');
      alias      |               description                |     token
-----------------+------------------------------------------+---------------
 numword         | Hyphenated word, letters and digits      | foo-bar-beta1
 hword_asciipart | Hyphenated word part, all ASCII          | foo
 blank           | Space symbols                            | -
 hword_asciipart | Hyphenated word part, all ASCII          | bar
 blank           | Space symbols                            | -
 hword_numpart   | Hyphenated word part, letters and digits | beta1
```

This behavior is desirable since it allows searches to work for both the whole compound word and for components. Here is another instructive example:

```
SELECT alias, description, token FROM ts_debug('http://example.com/stuff/index.html');
  alias   |  description  |            token
----------+---------------+------------------------------
 protocol | Protocol head | http://
 url      | URL           | example.com/stuff/index.html
 host     | Host          | example.com
 url_path | URL path      | /stuff/index.html
```

Parent topic: Using Full Text Search

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4.6.8.6 Text Search Dictionaries

Tokens produced by the WarehousePG full text search parser are passed through a chain of dictionaries to produce a normalized term or "lexeme". Different kinds of dictionaries are available to filter and transform tokens in different ways and for different languages.

This section contains the following subtopics:

- About Text Search Dictionaries
- Stop Words
- Simple Dictionary
- Synonym Dictionary
- Thesaurus Dictionary
- Ispell Dictionary
- SnowBall Dictionary

About Text Search Dictionaries

Dictionaries are used to eliminate words that should not be considered in a search (*stop words*), and to *normalize* words so that different derived forms of the same word will match. A successfully normalized word is called a*lexeme*. Aside from improving search quality, normalization and removal of stop words reduces the size of the `tsvector` representation of a document, thereby improving performance. Normalization does not always have linguistic meaning and usually depends on application semantics.

Some examples of normalization:

- Linguistic - Ispell dictionaries try to reduce input words to a normalized form; stemmer dictionaries remove word endings
- URL locations can be canonicalized to make equivalent URLs match:
  - `http://www.pgsql.ru/db/mw/index.html`
  - `http://www.pgsql.ru/db/mw/`
  - `http://www.pgsql.ru/db/../db/mw/index.html`
- Color names can be replaced by their hexadecimal values, e.g., `red`, `green`, `blue`, `magenta` -> `FF0000`, `00FF00`, `0000FF`, `FF00FF`
- If indexing numbers, we can remove some fractional digits to reduce the range of possible numbers, so for example 3.14159265359, 3.1415926, 3.14 will be the same after normalization if only two digits are kept after the decimal point.

A dictionary is a program that accepts a token as input and returns:

- an array of lexemes if the input token is known to the dictionary (notice that one token can produce more than one lexeme)
- a single lexeme with the `TSL_FILTER` flag set, to replace the original token with a new token to be passed to subsequent dictionaries (a dictionary that does this is called a*filtering dictionary*)
- an empty array if the dictionary knows the token, but it is a stop word
- `NULL` if the dictionary does not recognize the input token

WarehousePG provides predefined dictionaries for many languages. There are also several predefined templates that can be used to create new dictionaries with custom parameters. Each predefined dictionary template is described below. If no existing template is suitable, it is possible to create new ones; see the `contrib/` area of the WarehousePG distribution for examples.

A text search configuration binds a parser together with a set of dictionaries to process the parser's output tokens. For each token type that the parser can return, a separate list of dictionaries is specified by the configuration. When a token of that type is found by the parser, each dictionary in the list is consulted in turn, until some dictionary recognizes it as a known word. If it is identified as a stop word, or if no dictionary recognizes the token, it will be discarded and not indexed or searched for. Normally, the first dictionary that returns a `non-NULL` output determines the result, and any remaining dictionaries are not consulted; but a filtering dictionary can replace the given word with a modified word, which is then passed to subsequent dictionaries.

The general rule for configuring a list of dictionaries is to place first the most narrow, most specific dictionary, then the more general dictionaries, finishing with a very general dictionary, like a Snowball stemmer or `simple`, which recognizes everything. For example, for an astronomy-specific search (`astro_en` configuration) one could bind token type `asciiword` (ASCII word) to a synonym dictionary of astronomical terms, a general English dictionary and a Snowball English stemmer:

```
ALTER TEXT SEARCH CONFIGURATION astro_en
    ADD MAPPING FOR asciiword WITH astrosyn, english_ispell, english_stem;
```

A filtering dictionary can be placed anywhere in the list, except at the end where it'd be useless. Filtering dictionaries are useful to partially normalize words to simplify the task of later dictionaries. For example, a filtering dictionary could be used to remove accents from accented letters, as is done by the unaccent module.

Stop Words

Stop words are words that are very common, appear in almost every document, and have no discrimination value. Therefore, they can be ignored in the context of full text searching. For example, every English text contains words like `a` and `the`, so it is useless to store them in an index. However, stop words do affect the positions in `tsvector`, which in turn affect ranking:

```
SELECT to_tsvector('english', 'in the list of stop words');
        to_tsvector
----------------------------
 'list':3 'stop':5 'word':6
```

The missing positions 1,2,4 are because of stop words. Ranks calculated for documents with and without stop words are quite different:

```
SELECT ts_rank_cd (to_tsvector('english', 'in the list of stop words'), to_tsquery('list & stop'));
 ts_rank_cd
------------
       0.05

SELECT ts_rank_cd (to_tsvector('english', 'list stop words'), to_tsquery('list & stop'));
 ts_rank_cd
------------
        0.1
```

It is up to the specific dictionary how it treats stop words. For example, `ispell` dictionaries first normalize words and then look at the list of stop words, while `Snowball` stemmers first check the list of stop words. The reason for the different behavior is an attempt to decrease noise.

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Simple Dictionary

The simple dictionary template operates by converting the input token to lower case and checking it against a file of stop words. If it is found in the file then an empty array is returned, causing the token to be discarded. If not, the lower-cased form of the word is returned as the normalized lexeme. Alternatively, the dictionary can be configured to report non-stop-words as unrecognized, allowing them to be passed on to the next dictionary in the list.

Here is an example of a dictionary definition using the simple template:

```
CREATE TEXT SEARCH DICTIONARY public.simple_dict (
    TEMPLATE = pg_catalog.simple,
    STOPWORDS = english
);
```

Here, `english` is the base name of a file of stop words. The file's full name will be `$SHAREDIR/tsearch_data/english.stop`, where `$SHAREDIR` means the WarehousePG installation's shared-data directory, often `/usr/edb/whpg7/share/postgresql` (use `pg_config --sharedir` to determine it if you're not sure). The file format is simply a list of words, one per line. Blank lines and trailing spaces are ignored, and upper case is folded to lower case, but no other processing is done on the file contents.

Now we can test our dictionary:

```
SELECT ts_lexize('public.simple_dict', 'YeS');
 ts_lexize
-----------
 {yes}

SELECT ts_lexize('public.simple_dict', 'The');
 ts_lexize
-----------
 {}
```

We can also choose to return `NULL`, instead of the lower-cased word, if it is not found in the stop words file. This behavior is selected by setting the dictionary's `Accept` parameter to false. Continuing the example:

```
ALTER TEXT SEARCH DICTIONARY public.simple_dict ( Accept = false );

SELECT ts_lexize('public.simple_dict', 'YeS');
 ts_lexize
-----------
 {yes}

SELECT ts_lexize('public.simple_dict', 'The');
 ts_lexize
-----------
 {}
```

With the default setting of `Accept = true`, it is only useful to place a simple dictionary at the end of a list of dictionaries, since it will never pass on any token to a following dictionary. Conversely, `Accept = false` is only useful when there is at least one following dictionary.

CAUTION:

Most types of dictionaries rely on configuration files, such as files of stop words. These files *must* be stored in UTF-8 encoding. They will be translated to the actual database encoding, if that is different, when they are read into the server.

CAUTION:

Normally, a database session will read a dictionary configuration file only once, when it is first used within the session. If you modify a configuration file and want to force existing sessions to pick up the new contents, issue an `ALTER TEXT SEARCH DICTIONARY` command on the dictionary. This can be a "dummy" update that doesn't actually change any parameter values.

Synonym Dictionary

This dictionary template is used to create dictionaries that replace a word with a synonym. Phrases are not supported—use the thesaurus template (Thesaurus Dictionary) for that. A synonym dictionary can be used to overcome linguistic problems, for example, to prevent an English stemmer dictionary from reducing the word "Paris" to "pari". It is enough to have a `Paris paris` line in the synonym dictionary and put it before the `english_stem` dictionary. For example:

```
SELECT * FROM ts_debug('english', 'Paris');
   alias   |   description   | token |  dictionaries  |  dictionary  | lexemes
-----------+-----------------+-------+----------------+--------------+---------
 asciiword | Word, all ASCII | Paris | {english_stem} | english_stem | {pari}

CREATE TEXT SEARCH DICTIONARY my_synonym (
    TEMPLATE = synonym,
    SYNONYMS = my_synonyms
);

ALTER TEXT SEARCH CONFIGURATION english
    ALTER MAPPING FOR asciiword
    WITH my_synonym, english_stem;

SELECT * FROM ts_debug('english', 'Paris');
   alias   |   description   | token |       dictionaries        | dictionary | lexemes
-----------+-----------------+-------+---------------------------+------------+---------
 asciiword | Word, all ASCII | Paris | {my_synonym,english_stem} | my_synonym | {paris}
```

The only parameter required by the synonym template is `SYNONYMS`, which is the base name of its configuration file — `my_synonyms` in the above example. The file's full name will be `$SHAREDIR/tsearch_data/my_synonyms.syn` (where `$SHAREDIR` means the WarehousePG installation's shared-data directory). The file format is just one line per word to be substituted, with the word followed by its synonym, separated by white space. Blank lines and trailing spaces are ignored.

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The synonym template also has an optional parameter `CaseSensitive`, which defaults to `false`. When `CaseSensitive` is `false`, words in the synonym file are folded to lower case, as are input tokens. When it is `true`, words and tokens are not folded to lower case, but are compared as-is.

An asterisk (*) can be placed at the end of a synonym in the configuration file. This indicates that the synonym is a prefix. The asterisk is ignored when the entry is used in `to_tsvector()`, but when it is used in `to_tsquery()`, the result will be a query item with the prefix match marker (see Parsing Queries). For example, suppose we have these entries in `$SHAREDIR/tsearch_data/synonym_sample.syn`:

```
postgres pgsql postgresql pgsql postgre pgsql
gogle googl
indices index*
```

Then we will get these results:

```
mydb=# CREATE TEXT SEARCH DICTIONARY syn (template=synonym, synonyms='synonym_sample');
mydb=# SELECT ts_lexize('syn', 'indices');
 ts_lexize
-----------
 {index}
(1 row)

mydb=# CREATE TEXT SEARCH CONFIGURATION tst (copy=simple);
mydb=# ALTER TEXT SEARCH CONFIGURATION tst ALTER MAPPING FOR asciiword WITH syn;
mydb=# SELECT to_tsvector('tst', 'indices');
 to_tsvector
-------------
 'index':1
(1 row)

mydb=# SELECT to_tsquery('tst', 'indices');
 to_tsquery
------------
 'index':*
(1 row)

mydb=# SELECT 'indexes are very useful'::tsvector;
            tsvector
---------------------------------
 'are' 'indexes' 'useful' 'very'
(1 row)

mydb=# SELECT 'indexes are very useful'::tsvector @@ to_tsquery('tst', 'indices');
 ?column?
----------
 t
(1 row)
```

Thesaurus Dictionary

A thesaurus dictionary (sometimes abbreviated as TZ) is a collection of words that includes information about the relationships of words and phrases, i.e., broader terms (BT), narrower terms (NT), preferred terms, non-preferred terms, related terms, etc.

Basically a thesaurus dictionary replaces all non-preferred terms by one preferred term and, optionally, preserves the original terms for indexing as well. WarehousePG's current implementation of the thesaurus dictionary is an extension of the synonym dictionary with added *phrase* support. A thesaurus dictionary requires a configuration file of the following format:

```
# this is a comment
sample word(s) : indexed word(s)
more sample word(s) : more indexed word(s)
...
```

where the colon (`:`) symbol acts as a delimiter between a phrase and its replacement.

A thesaurus dictionary uses a *subdictionary* (which is specified in the dictionary's configuration) to normalize the input text before checking for phrase matches. It is only possible to select one subdictionary. An error is reported if the subdictionary fails to recognize a word. In that case, you should remove the use of the word or teach the subdictionary about it. You can place an asterisk (`*`) at the beginning of an indexed word to skip applying the subdictionary to it, but all sample words **must** be known to the subdictionary.

The thesaurus dictionary chooses the longest match if there are multiple phrases matching the input, and ties are broken by using the last definition.

Specific stop words recognized by the subdictionary cannot be specified; instead use `?` to mark the location where any stop word can appear. For example, assuming that `a` and `the` are stop words according to the subdictionary:

```
? one ? two : swsw
```

matches `a one the two` and `the one a two`; both would be replaced by `swsw`.

Since a thesaurus dictionary has the capability to recognize phrases it must remember its state and interact with the parser. A thesaurus dictionary uses these assignments to check if it should handle the next word or stop accumulation. The thesaurus dictionary must be configured carefully. For example, if the thesaurus dictionary is assigned to handle only the `asciiword` token, then a thesaurus dictionary definition like `one 7` will not work since token type `uint` is not assigned to the thesaurus dictionary.

CAUTION:

Thesauruses are used during indexing so any change in the thesaurus dictionary's parameters requires reindexing. For most other dictionary types, small changes such as adding or removing stopwords does not force reindexing.

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Thesaurus Configuration

To define a new thesaurus dictionary, use the `thesaurus` template. For example:

```
CREATE TEXT SEARCH DICTIONARY thesaurus_simple (
    TEMPLATE = thesaurus,
    DictFile = mythesaurus,
    Dictionary = pg_catalog.english_stem
);
```

Here:

- `thesaurus_simple` is the new dictionary's name
- `mythesaurus` is the base name of the thesaurus configuration file. (Its full name will be `$SHAREDIR/tsearch_data/mythesaurus.ths`, where `$SHAREDIR` means the installation shared-data directory.)
- `pg_catalog.english_stem` is the subdictionary (here, a Snowball English stemmer) to use for thesaurus normalization. Notice that the subdictionary will have its own configuration (for example, stop words), which is not shown here.

Now it is possible to bind the thesaurus dictionary `thesaurus_simple` to the desired token types in a configuration, for example:

```
ALTER TEXT SEARCH CONFIGURATION russian
    ALTER MAPPING FOR asciiword, asciihword, hword_asciipart
    WITH thesaurus_simple;
```

Thesaurus Example

Consider a simple astronomical thesaurus `thesaurus_astro`, which contains some astronomical word combinations:

```
supernovae stars : sn
crab nebulae : crab
```

Below we create a dictionary and bind some token types to an astronomical thesaurus and English stemmer:

```
CREATE TEXT SEARCH DICTIONARY thesaurus_astro (
    TEMPLATE = thesaurus,
    DictFile = thesaurus_astro,
    Dictionary = english_stem
);

ALTER TEXT SEARCH CONFIGURATION russian
    ALTER MAPPING FOR asciiword, asciihword, hword_asciipart
    WITH thesaurus_astro, english_stem;
```

Now we can see how it works. `ts_lexize` is not very useful for testing a thesaurus, because it treats its input as a single token. Instead we can use `plainto_tsquery` and `to_tsvector`, which will break their input strings into multiple tokens:

```
SELECT plainto_tsquery('supernova star');
 plainto_tsquery
-----------------
 'supernova' & 'star'

SELECT to_tsvector('supernova star');
 to_tsvector
-------------
 'star':2 'supernova':1
```

In principle, one can use `to_tsquery` if you quote the argument:

```
SELECT to_tsquery('''supernova star''');
 to_tsquery
------------
 'supernova' & 'star'
```

Notice that `supernova star` matches `supernovae stars` in `thesaurus_astro` because we specified the `english_stem` stemmer in the `thesaurus` definition. The stemmer removed the `e` and `s`.

To index the original phrase as well as the substitute, just include it in the right-hand part of the definition:

```
supernovae stars : sn supernovae stars

SELECT plainto_tsquery('supernova star');
       plainto_tsquery
-----------------------------
 'supernova' & 'star'
```

Ispell Dictionary

The Ispell dictionary template supports *morphological dictionaries*, which can normalize many different linguistic forms of a word into the same lexeme. For example, an English Ispell dictionary can match all declensions and conjugations of the search term `bank`, e.g., `banking`, `banked`, `banks`, `banks'`, and `bank's`.

The standard WarehousePG distribution does not include any Ispell configuration files. Dictionaries for a large number of languages are available from Ispell. Also, some more modern dictionary file formats are supported — MySpell (OO < 2.0.1) and Hunspell (OO >= 2.0.2). A large list of dictionaries is available on the OpenOffice Wiki.

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To create an Ispell dictionary perform these steps:

1. Download dictionary configuration files. OpenOffice extension files have the `.oxt` extension. It is necessary to extract `.aff` and `.dic` files, change extensions to `.affix` and `.dict`. For some dictionary files it is also needed to convert characters to the UTF-8 encoding with commands (for example, for a Norwegian language dictionary):

   ```
   iconv -f ISO_8859-1 -t UTF-8 -o nn_no.affix nn_NO.aff
   iconv -f ISO_8859-1 -t UTF-8 -o nn_no.dict nn_NO.dic
   ```

2. Copy files to the `$SHAREDIR/tsearch_data` directory.

3. Load files into PostgreSQL with the following command:

   ```
   CREATE TEXT SEARCH DICTIONARY english_hunspell (
   TEMPLATE = ispell,
   DictFile = en_us,
   AffFile = en_us,
   Stopwords = english);
   ```

Here, `DictFile`, `AffFile`, and `StopWords` specify the base names of the dictionary, affixes, and stop-words files. The stop-words file has the same format explained above for the `simple` dictionary type. The format of the other files is not specified here but is available from the above-mentioned web sites.

Ispell dictionaries usually recognize a limited set of words, so they should be followed by another broader dictionary; for example, a Snowball dictionary, which recognizes everything.

The `.affix` file of Ispell has the following structure:

```
prefixes
flag *A:
    .           >   RE      # As in enter > reenter
suffixes
flag T:
    E           >   ST      # As in late > latest
    [^AEIOU]Y   >   -Y,IEST # As in dirty > dirtiest
    [AEIOU]Y    >   EST     # As in gray > grayest
    [^EY]       >   EST     # As in small > smallest
```

And the `.dict` file has the following structure:

```
lapse/ADGRS
lard/DGRS
large/PRTY
lark/MRS
```

Format of the `.dict` file is:

```
basic_form/affix_class_name
```

In the `.affix` file every affix flag is described in the following format:

```
condition > [-stripping_letters,] adding_affix
```

Here, condition has a format similar to the format of regular expressions. It can use groupings `[...]` and `[^...]`. For example, `[AEIOU]Y` means that the last letter of the word is "y" and the penultimate letter is "a", "e", "i", "o" or "u". `[^EY]` means that the last letter is neither "e" nor "y".

Ispell dictionaries support splitting compound words; a useful feature. Notice that the affix file should specify a special flag using the `compoundwords controlled` statement that marks dictionary words that can participate in compound formation:

```
compoundwords  controlled z
```

Here are some examples for the Norwegian language:

```
SELECT ts_lexize('norwegian_ispell', 'overbuljongterningpakkmesterassistent');
   {over,buljong,terning,pakk,mester,assistent}
SELECT ts_lexize('norwegian_ispell', 'sjokoladefabrikk');
   {sjokoladefabrikk,sjokolade,fabrikk}
```

MySpell format is a subset of Hunspell. The `.affix` file of Hunspell has the following structure:

```
PFX A Y 1
PFX A   0     re         .
SFX T N 4
SFX T   0     st         e
SFX T   y     iest       [^aeiou]y
SFX T   0     est        [aeiou]y
SFX T   0     est        [^ey]
```

The first line of an affix class is the header. Fields of an affix rules are listed after the header:

- parameter name (PFX or SFX)
- flag (name of the affix class)

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- stripping characters from beginning (at prefix) or end (at suffix) of the word
- adding affix
- condition that has a format similar to the format of regular expressions.

The `.dict` file looks like the `.dict` file of Ispell:

```
larder/M
lardy/RT
large/RSPMYT
largehearted
```

> **Note** MySpell does not support compound words. Hunspell has sophisticated support for compound words. At present, WarehousePG implements only the basic compound word operations of Hunspell.

SnowBall Dictionary

The Snowball dictionary template is based on a project by Martin Porter, inventor of the popular Porter's stemming algorithm for the English language. Snowball now provides stemming algorithms for many languages (see the Snowball site for more information). Each algorithm understands how to reduce common variant forms of words to a base, or stem, spelling within its language. A Snowball dictionary requires a language parameter to identify which stemmer to use, and optionally can specify a stopword file name that gives a list of words to eliminate. (WarehousePG's standard stopword lists are also provided by the Snowball project.) For example, there is a built-in definition equivalent to

```
CREATE TEXT SEARCH DICTIONARY english_stem (
    TEMPLATE = snowball,
    Language = english,
    StopWords = english
);
```

The stopword file format is the same as already explained.

A Snowball dictionary recognizes everything, whether or not it is able to simplify the word, so it should be placed at the end of the dictionary list. It is useless to have it before any other dictionary because a token will never pass through it to the next dictionary.

Parent topic: Using Full Text Search

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4.6.8.7 Text Search Configuration Example

This topic shows how to create a customized text search configuration to process document and query text.

A text search configuration specifies all options necessary to transform a document into a `tsvector` : the parser to use to break text into tokens, and the dictionaries to use to transform each token into a lexeme. Every call of `to_tsvector` or `to_tsquery` needs a text search configuration to perform its processing. The configuration parameter default_text_search_config specifies the name of the default configuration, which is the one used by text search functions if an explicit configuration parameter is omitted. It can be set in `postgresql.conf` using the `gpconfig` command-line utility, or set for an individual session using the `SET` command.

Several predefined text search configurations are available, and you can create custom configurations easily. To facilitate management of text search objects, a set of SQL commands is available, and there are several psql commands that display information about text search objects (psql Support).

As an example we will create a configuration `pg` , starting by duplicating the built-in `english` configuration:

```
CREATE TEXT SEARCH CONFIGURATION public.pg ( COPY = pg_catalog.english );
```

We will use a PostgreSQL-specific synonym list and store it in `$SHAREDIR/tsearch_data/pg_dict.syn` . The file contents look like:

```
postgres    pg
pgsql       pg
postgresql  pg
```

We define the synonym dictionary like this:

```
CREATE TEXT SEARCH DICTIONARY pg_dict (
    TEMPLATE = synonym,
    SYNONYMS = pg_dict
);
```

Next we register the Ispell dictionary `english_ispell` , which has its own configuration files:

```
CREATE TEXT SEARCH DICTIONARY english_ispell (
    TEMPLATE = ispell,
    DictFile = english,
    AffFile = english,
    StopWords = english
);
```

Now we can set up the mappings for words in configuration `pg` :

```
ALTER TEXT SEARCH CONFIGURATION pg
    ALTER MAPPING FOR asciiword, asciihword, hword_asciipart,
                      word, hword, hword_part
    WITH pg_dict, english_ispell, english_stem;
```

We choose not to index or search some token types that the built-in configuration does handle:

```
ALTER TEXT SEARCH CONFIGURATION pg
    DROP MAPPING FOR email, url, url_path, sfloat, float;
```

Now we can test our configuration:

```
SELECT * FROM ts_debug('public.pg', '
PostgreSQL, the highly scalable, SQL compliant, open source object-relational
database management system, is now undergoing beta testing of the next
version of our software.
');
```

The next step is to set the session to use the new configuration, which was created in the `public` schema:

```
=> \dF
   List of text search configurations
 Schema  | Name | Description
---------+------+-------------
 public  | pg   |

SET default_text_search_config = 'public.pg';
SET

SHOW default_text_search_config;
 default_text_search_config
----------------------------
 public.pg
```

Parent topic: Using Full Text Search

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4.6.8.8 Testing and Debugging Text Search

This topic introduces the WarehousePG functions you can use to test and debug a search configuration or the individual parser and dictionaries specified in a configuration.

The behavior of a custom text search configuration can easily become confusing. The functions described in this section are useful for testing text search objects. You can test a complete configuration, or test parsers and dictionaries separately.

This section contains the following subtopics:

- Configuration Testing
- Parser Testing
- Dictionary Testing

Configuration Testing

The function `ts_debug` allows easy testing of a text search configuration.

```
ts_debug([<config> regconfig, ] <document> text,
         OUT <alias> text,
         OUT <description> text,
         OUT <token> text,
         OUT <dictionaries> regdictionary[],
         OUT <dictionary> regdictionary,
         OUT <lexemes> text[])
         returns setof record
```

`ts_debug` displays information about every token of `*document*` as produced by the parser and processed by the configured dictionaries. It uses the configuration specified by `*config*`, or `default_text_search_config` if that argument is omitted.

`ts_debug` returns one row for each token identified in the text by the parser. The columns returned are

- `*alias* text` — short name of the token type
- `*description* text` — description of the token type
- `*token* text` — text of the token
- `*dictionaries* regdictionary[]` — the dictionaries selected by the configuration for this token type
- `*dictionary* regdictionary` — the dictionary that recognized the token, or `NULL` if none did
- `*lexemes* text[]` — the lexeme(s) produced by the dictionary that recognized the token, or `NULL` if none did; an empty array (`{}`) means it was recognized as a stop word

Here is a simple example:

```
SELECT * FROM ts_debug('english', 'a fat  cat sat on a mat - it ate a fat rats');
   alias   |   description   | token |  dictionaries  |  dictionary  | lexemes
-----------+-----------------+-------+----------------+--------------+---------
 asciiword | Word, all ASCII | a     | {english_stem} | english_stem | {}
 blank     | Space symbols   |       | {}             |              |
 asciiword | Word, all ASCII | fat   | {english_stem} | english_stem | {fat}
 blank     | Space symbols   |       | {}             |              |
 asciiword | Word, all ASCII | cat   | {english_stem} | english_stem | {cat}
 blank     | Space symbols   |       | {}             |              |
 asciiword | Word, all ASCII | sat   | {english_stem} | english_stem | {sat}
 blank     | Space symbols   |       | {}             |              |
 asciiword | Word, all ASCII | on    | {english_stem} | english_stem | {}
 blank     | Space symbols   |       | {}             |              |
 asciiword | Word, all ASCII | a     | {english_stem} | english_stem | {}
 blank     | Space symbols   |       | {}             |              |
 asciiword | Word, all ASCII | mat   | {english_stem} | english_stem | {mat}
 blank     | Space symbols   |       | {}             |              |
 blank     | Space symbols   | -     | {}             |              |
 asciiword | Word, all ASCII | it    | {english_stem} | english_stem | {}
 blank     | Space symbols   |       | {}             |              |
 asciiword | Word, all ASCII | ate   | {english_stem} | english_stem | {ate}
 blank     | Space symbols   |       | {}             |              |
 asciiword | Word, all ASCII | a     | {english_stem} | english_stem | {}
 blank     | Space symbols   |       | {}             |              |
 asciiword | Word, all ASCII | fat   | {english_stem} | english_stem | {fat}
 blank     | Space symbols   |       | {}             |              |
 asciiword | Word, all ASCII | rats  | {english_stem} | english_stem | {rat}
```

For a more extensive demonstration, we first create a `public.english` configuration and Ispell dictionary for the English language:

```
CREATE TEXT SEARCH CONFIGURATION public.english ( COPY = pg_catalog.english );

CREATE TEXT SEARCH DICTIONARY english_ispell (
    TEMPLATE = ispell,
    DictFile = english,
    AffFile = english,
    StopWords = english
);

ALTER TEXT SEARCH CONFIGURATION public.english
   ALTER MAPPING FOR asciiword WITH english_ispell, english_stem;
```

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```
SELECT * FROM ts_debug('public.english', 'The Brightest supernovaes');
   alias   |   description   |    token    |         dictionaries          |   dictionary   |   lexemes
-----------+-----------------+-------------+-------------------------------+----------------+-------------
 asciiword | Word, all ASCII | The         | {english_ispell,english_stem} | english_ispell | {}
 blank     | Space symbols   |             | {}                            |                |
 asciiword | Word, all ASCII | Brightest   | {english_ispell,english_stem} | english_ispell | {bright}
 blank     | Space symbols   |             | {}                            |                |
 asciiword | Word, all ASCII | supernovaes | {english_ispell,english_stem} | english_stem   | {supernova}
```

In this example, the word `Brightest` was recognized by the parser as an `ASCII` word (alias `asciiword`). For this token type the dictionary list is `english_ispell` and `english_stem`. The word was recognized by `english_ispell`, which reduced it to the noun `bright`. The word `supernovaes` is unknown to the `english_ispell` dictionary so it was passed to the next dictionary, and, fortunately, was recognized (in fact, `english_stem` is a Snowball dictionary which recognizes everything; that is why it was placed at the end of the dictionary list).

The word `The` was recognized by the `english_ispell` dictionary as a stop word (Stop Words) and will not be indexed. The spaces are discarded too, since the configuration provides no dictionaries at all for them.

You can reduce the width of the output by explicitly specifying which columns you want to see:

```
SELECT alias, token, dictionary, lexemes FROM ts_debug('public.english', 'The Brightest supernovaes');
  alias    |    token    |   dictionary   |    lexemes
-----------+-------------+----------------+-------------
 asciiword | The         | english_ispell | {}
 blank     |             |                |
 asciiword | Brightest   | english_ispell | {bright}
 blank     |             |                |
 asciiword | supernovaes | english_stem   | {supernova}
```

Parser Testing

The following functions allow direct testing of a text search parser.

```
ts_parse(<parser_name> text, <document> text,
         OUT <tokid> integer, OUT <token> text) returns setof record
ts_parse(<parser_oid> oid, <document> text,
         OUT <tokid> integer, OUT <token> text) returns setof record
```

`ts_parse` parses the given document and returns a series of records, one for each token produced by parsing. Each record includes a `tokid` showing the assigned token type and a `token`, which is the text of the token. For example:

```
SELECT * FROM ts_parse('default', '123 - a number');
 tokid | token
-------+--------
    22 | 123
    12 |
    12 | -
     1 | a
    12 |
     1 | number
```

```
ts_token_type(<parser_name> text, OUT <tokid> integer,
              OUT <alias> text, OUT <description> text) returns setof record
ts_token_type(<parser_oid> oid, OUT <tokid> integer,
              OUT <alias> text, OUT <description> text) returns setof record
```

`ts_token_type` returns a table which describes each type of token the specified parser can recognize. For each token type, the table gives the integer `tokid` that the parser uses to label a token of that type, the `alias` that names the token type in configuration commands, and a short `description`. For example:

```
SELECT * FROM ts_token_type('default');
 tokid |      alias      |               description
-------+-----------------+------------------------------------------
     1 | asciiword       | Word, all ASCII
     2 | word            | Word, all letters
     3 | numword         | Word, letters and digits
     4 | email           | Email address
     5 | url             | URL
     6 | host            | Host
     7 | sfloat          | Scientific notation
     8 | version         | Version number
     9 | hword_numpart   | Hyphenated word part, letters and digits
    10 | hword_part      | Hyphenated word part, all letters
    11 | hword_asciipart | Hyphenated word part, all ASCII
    12 | blank           | Space symbols
    13 | tag             | XML tag
    14 | protocol        | Protocol head
    15 | numhword        | Hyphenated word, letters and digits
    16 | asciihword      | Hyphenated word, all ASCII
    17 | hword           | Hyphenated word, all letters
    18 | url_path        | URL path
    19 | file            | File or path name
    20 | float           | Decimal notation
    21 | int             | Signed integer
    22 | uint            | Unsigned integer
    23 | entity          | XML entity
```

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Dictionary Testing

The `ts_lexize` function facilitates dictionary testing.

```
ts_lexize(*dictreg* dictionary, *token* text) returns text[]
```

`ts_lexize` returns an array of lexemes if the input `*token*` is known to the dictionary, or an empty array if the token is known to the dictionary but it is a stop word, or `NULL` if it is an unknown word.

Examples:

```
SELECT ts_lexize('english_stem', 'stars');
 ts_lexize
-----------
 {star}

SELECT ts_lexize('english_stem', 'a');
 ts_lexize
-----------
 {}
```

> **Note** The `ts_lexize` function expects a single token, not text. Here is a case where this can be confusing:

```
SELECT ts_lexize('thesaurus_astro','supernovae stars') is null;
 ?column?
----------
 t
```

The thesaurus dictionary `thesaurus_astro` does know the phrase `supernovae stars`, but `ts_lexize` fails since it does not parse the input text but treats it as a single token. Use `plainto_tsquery` or `to_tsvector` to test thesaurus dictionaries, for example:

```
SELECT plainto_tsquery('supernovae stars');
 plainto_tsquery
-----------------
 'sn'
```

Parent topic: Using Full Text Search

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4.6.8.9 Preferred Index Types for Text Search

There are two kinds of indexes that can be used to speed up full text searches: GIN and GiST. Indexes are not mandatory for full text searching, but in cases where a column is searched on a regular basis, an index is usually desirable.

To create such an index, do one of:

`CREATE INDEX <name> ON <table> USING gin(<column>);` Creates a GIN (Generalized Inverted Index)-based index. The `<column>` must be of `tsvector` type.

`CREATE INDEX <name> ON <table> USING gist(<column>);` Creates a GiST (Generalized Search Tree)-based index. The `<column>` can be of `tsvector` or `tsquery` type.

GIN indexes are the preferred text search index type. As inverted indexes, they contain an index entry for each word (lexeme), with a compressed list of matching locations. Multi-word searches can find the first match, then use the index to remove rows that are lacking additional words. GIN indexes store only the words (lexemes) of `tsvector` values, and not their weight labels. Thus a table row recheck is needed when using a query that involves weights.

A GiST index is lossy, meaning that the index might produce false matches, and it is necessary to check the actual table row to eliminate such false matches. (PostgreSQL does this automatically when needed.) GiST indexes are lossy because each document is represented in the index by a fixed-length signature. The signature is generated by hashing each word into a single bit in an n-bit string, with all these bits OR-ed together to produce an n-bit document signature. When two words hash to the same bit position there will be a false match. If all words in the query have matches (real or false) then the table row must be retrieved to see if the match is correct.

A GiST index can be covering, i.e., use the `INCLUDE` clause. Included columns can have data types without any GiST operator class. Included attributes will be stored uncompressed.

Lossiness causes performance degradation due to unnecessary fetches of table records that turn out to be false matches. Since random access to table records is slow, this limits the usefulness of GiST indexes. The likelihood of false matches depends on several factors, in particular the number of unique words, so using dictionaries to reduce this number is recommended.

Note that GIN index build time can often be improved by increasing maintenance_work_mem, while GiST index build time is not sensitive to that parameter.

Partitioning of big collections and the proper use of GiST and GIN indexes allows the implementation of very fast searches with online update. Partitioning can be done at the database level using table inheritance, or by distributing documents over servers and collecting search results using dblink. The latter is possible because ranking functions use only local information.

Parent topic: Using Full Text Search

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4.6.8.10 psql Support

The psql command-line utility provides a meta-command to display information about WarehousePG full text search configurations.

Information about text search configuration objects can be obtained in psql using a set of commands:

```
\dF{d,p,t}[+] [PATTERN]
```

An optional `+` produces more details.

The optional parameter `PATTERN` can be the name of a text search object, optionally schema-qualified. If `PATTERN` is omitted then information about all visible objects will be displayed. `PATTERN` can be a regular expression and can provide **separate** patterns for the schema and object names. The following examples illustrate this:

```
=> \dF *fulltext*
       List of text search configurations
 Schema |  Name        | Description
--------+--------------+-------------
 public | fulltext_cfg |
```

```
=> \dF *.fulltext*
       List of text search configurations
 Schema   |  Name        | Description
----------+--------------------------
 fulltext | fulltext_cfg |
 public   | fulltext_cfg |
```

The available commands are:

`\dF[+] [PATTERN]` List text search configurations (add `+` for more detail).

```
=> \dF russian
            List of text search configurations
   Schema   |  Name   |            Description
------------+---------+-----------------------------------
 pg_catalog | russian | configuration for russian language

=> \dF+ russian
Text search configuration "pg_catalog.russian"
Parser: "pg_catalog.default"
      Token      | Dictionaries
-----------------+--------------
 asciihword      | english_stem
 asciiword       | english_stem
 email           | simple
 file            | simple
 float           | simple
 host            | simple
 hword           | russian_stem
 hword_asciipart | english_stem
 hword_numpart   | simple
 hword_part      | russian_stem
 int             | simple
 numhword        | simple
 numword         | simple
 sfloat          | simple
 uint            | simple
 url             | simple
 url_path        | simple
 version         | simple
 word            | russian_stem
```

`\dFd[+] [PATTERN]` List text search dictionaries (add `+` for more detail).

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```
=> \dFd
                            List of text search dictionaries
   Schema   |      Name       |                        Description
------------+-----------------+-------------------------------------------------------------
 pg_catalog | arabic_stem     | snowball stemmer for arabic language
 pg_catalog | danish_stem     | snowball stemmer for danish language
 pg_catalog | dutch_stem      | snowball stemmer for dutch language
 pg_catalog | english_stem    | snowball stemmer for english language
 pg_catalog | finnish_stem    | snowball stemmer for finnish language
 pg_catalog | french_stem     | snowball stemmer for french language
 pg_catalog | german_stem     | snowball stemmer for german language
 pg_catalog | hungarian_stem  | snowball stemmer for hungarian language
 pg_catalog | indonesian_stem | snowball stemmer for indonesian language
 pg_catalog | irish_stem      | snowball stemmer for irish language
 pg_catalog | italian_stem    | snowball stemmer for italian language
 pg_catalog | lithuanian_stem | snowball stemmer for lithuanian language
 pg_catalog | nepali_stem     | snowball stemmer for nepali language
 pg_catalog | norwegian_stem  | snowball stemmer for norwegian language
 pg_catalog | portuguese_stem | snowball stemmer for portuguese language
 pg_catalog | romanian_stem   | snowball stemmer for romanian language
 pg_catalog | russian_stem    | snowball stemmer for russian language
 pg_catalog | simple          | simple dictionary: just lower case and check for stopword
 pg_catalog | spanish_stem    | snowball stemmer for spanish language
 pg_catalog | swedish_stem    | snowball stemmer for swedish language
 pg_catalog | tamil_stem      | snowball stemmer for tamil language
 pg_catalog | turkish_stem    | snowball stemmer for turkish language
```

\dFp[+] [PATTERN] List text search parsers (add `+` for more detail).

```
=> \dFp
        List of text search parsers
   Schema   |  Name   |     Description
------------+---------+---------------------
 pg_catalog | default | default word parser
=> \dFp+
    Text search parser "pg_catalog.default"
     Method      |    Function    | Description
-----------------+----------------+-------------
 Start parse     | prsd_start     |
 Get next token  | prsd_nexttoken |
 End parse       | prsd_end       |
 Get headline    | prsd_headline  |
 Get token types | prsd_lextype   |

        Token types for parser "pg_catalog.default"
   Token name    |               Description
-----------------+------------------------------------------
 asciihword      | Hyphenated word, all ASCII
 asciiword       | Word, all ASCII
 blank           | Space symbols
 email           | Email address
 entity          | XML entity
 file            | File or path name
 float           | Decimal notation
 host            | Host
 hword           | Hyphenated word, all letters
 hword_asciipart | Hyphenated word part, all ASCII
 hword_numpart   | Hyphenated word part, letters and digits
 hword_part      | Hyphenated word part, all letters
 int             | Signed integer
 numhword        | Hyphenated word, letters and digits
 numword         | Word, letters and digits
 protocol        | Protocol head
 sfloat          | Scientific notation
 tag             | XML tag
 uint            | Unsigned integer
 url             | URL
 url_path        | URL path
 version         | Version number
 word            | Word, all letters
(23 rows)
```

`\dFt[+] [PATTERN]` List text search templates (add + for more detail).

```
=> \dFt
                          List of text search templates
   Schema   |   Name    |                       Description
------------+-----------+-------------------------------------------------------------
 pg_catalog | ispell    | ispell dictionary
 pg_catalog | simple    | simple dictionary: just lower case and check for stopword
 pg_catalog | snowball  | snowball stemmer
 pg_catalog | synonym   | synonym dictionary: replace word by its synonym
 pg_catalog | thesaurus | thesaurus dictionary: phrase by phrase substitution
```

Parent topic: Using Full Text Search

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4.6.8.11 Limitations

This topic lists limitations and maximums for WarehousePG full text search objects.

The current limitations of WarehousePG's text search features are:

- The `tsvector` and `tsquery` types are not supported in the distribution key for a WarehousePG table
- The length of each lexeme must be less than 2K bytes
- The length of a `tsvector` (lexemes + positions) must be less than 1 megabyte
- The match distance in a `<N>` (FOLLOWED BY) `tsquery` operator cannot be more than 16,384
- The number of lexemes must be less than 264
- Position values in `tsvector` must be greater than 0 and no more than 16,383
- No more than 256 positions per lexeme
- The number of nodes (lexemes + operators) in a tsquery must be less than 32,768

For comparison, the PostgreSQL 8.1 documentation contained 10,441 unique words, a total of 335,420 words, and the most frequent word "postgresql" was mentioned 6,127 times in 655 documents.

Another example — the PostgreSQL mailing list archives contained 910,989 unique words with 57,491,343 lexemes in 461,020 messages.

Parent topic: Using Full Text Search

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4.6.9 Query Performance

WarehousePG dynamically eliminates irrelevant partitions in a table and optimally allocates memory for different operators in a query.These enhancements scan less data for a query, accelerate query processing, and support more concurrency.

- Dynamic Partition Elimination

  In WarehousePG, values available only when a query runs are used to dynamically prune partitions, which improves query processing speed. Enable or deactivate dynamic partition elimination by setting the server configuration parameter `gp_dynamic_partition_pruning` to `ON` or `OFF`; it is `ON` by default.

- Memory Optimizations

  WarehousePG allocates memory optimally for different operators in a query and frees and re-allocates memory during the stages of processing a query.

> **Note** WarehousePG uses GPORCA, the WarehousePG next generation query optimizer, by default. GPORCA extends the planning and optimization capabilities of the Postgres optimizer. For information about the features and limitations of GPORCA, see Overview of GPORCA.

Parent topic: SQL: Querying Data

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4.6.10 Managing Spill Files Generated by Queries

WarehousePG creates spill files, also known as workfiles, on disk if it does not have sufficient memory to run an SQL query in memory.

The maximum number of spill files for a given query is governed by the gp_workfile_limit_files_per_query server configuration parameter setting. The default value of 100,000 spill files is sufficient for the majority of queries.

If a query creates more than the configured number of spill files, WarehousePG returns this error:

```
ERROR: number of workfiles per query limit exceeded
```

WarehousePG may generate a large number of spill files when:

- Data skew is present in the queried data. To check for data skew, see Checking for Data Distribution Skew.
- The amount of memory allocated for the query is too low. You control the maximum amount of memory that can be used by a query with the WarehousePG server configuration parametersmax_statement_mem and statement_mem, or through resource group or resource queue configuration.

You might be able to run the query successfully by changing the query, changing the data distribution, or changing the system memory configuration. The `gp_toolkit` *gp_workfile_** views display spill file usage information. You can use this information to troubleshoot and tune queries. The *gp_workfile_** views are described in Checking Query Disk Spill Space Usage.

Additional documentation resources:

- Memory Consumption Parameters identifies the memory-related spill file server configuration parameters.
- Using Resource Groups describes memory and spill considerations when resource group-based resource management is active.
- Using Resource Queues describes memory and spill considerations when resource queue-based resource management is active.

Parent topic: SQL: Querying Data

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4.6.11 Query Profiling

Examine the query plans of poorly performing queries to identify possible performance tuning opportunities.

WarehousePG devises a *query plan* for each query. Choosing the right query plan to match the query and data structure is necessary for good performance. A query plan defines how WarehousePG will run the query in the parallel execution environment.

The query optimizer uses data statistics maintained by the database to choose a query plan with the lowest possible cost. Cost is measured in disk I/O, shown as units of disk page fetches. The goal is to minimize the total execution cost for the plan.

View the plan for a given query with the `EXPLAIN` command. `EXPLAIN` shows the query optimizer's estimated cost for the query plan. For example:

```
EXPLAIN SELECT * FROM names WHERE id=22;
```

`EXPLAIN ANALYZE` runs the statement in addition to displaying its plan. This is useful for determining how close the optimizer's estimates are to reality. For example:

```
EXPLAIN ANALYZE SELECT * FROM names WHERE id=22;
```

> **Note** In WarehousePG, the default GPORCA optimizer co-exists with the Postgres-based planner. The EXPLAIN output generated by GPORCA is different than the output generated by the Postgres-based planner.

By default, WarehousePG uses GPORCA to generate an execution plan for a query when possible.

When the `EXPLAIN ANALYZE` command uses GPORCA, the `EXPLAIN` plan shows only the number of partitions that are being eliminated. The scanned partitions are not shown. To show name of the scanned partitions in the segment logs set the server configuration parameter `gp_log_dynamic_partition_pruning` to `on`. This example `SET` command enables the parameter.

```
SET gp_log_dynamic_partition_pruning = on;
```

For information about GPORCA, see SQL: Querying Data.

Parent topic: SQL: Querying Data

Reading EXPLAIN Output

A query plan is a tree of nodes. Each node in the plan represents a single operation, such as a table scan, join, aggregation, or sort.

Read plans from the bottom to the top: each node feeds rows into the node directly above it. The bottom nodes of a plan are usually table scan operations: sequential, index, or bitmap index scans. If the query requires joins, aggregations, sorts, or other operations on the rows, there are additional nodes above the scan nodes to perform these operations. The topmost plan nodes are usually WarehousePG motion nodes: redistribute, explicit redistribute, broadcast, or gather motions. These operations move rows between segment instances during query processing.

The output of `EXPLAIN` has one line for each node in the plan tree and shows the basic node type and the following execution cost estimates for that plan node:

- **cost** —Measured in units of disk page fetches. 1.0 equals one sequential disk page read. The first estimate is the start-up cost of getting the first row and the second is the total cost of cost of getting all rows. The total cost assumes all rows will be retrieved, which is not always true; for example, if the query uses `LIMIT`, not all rows are retrieved.

  > **Note** The cost values generated by GPORCA and the Postgres-based planner are not directly comparable. The two optimizers use different cost models, as well as different algorithms, to determine the cost of an execution plan. Nothing can or should be inferred by comparing cost values between the two optimizers.

  In addition, the cost generated for any given optimizer is valid only for comparing plan alternatives for a given single query and set of statistics. Different queries can generate plans with different costs, even when keeping the optimizer a constant.

  To summarize, the cost is essentially an internal number used by a given optimizer, and nothing should be inferred by examining only the cost value displayed in the `EXPLAIN` plans.

- **rows** —The total number of rows output by this plan node. This number is usually less than the number of rows processed or scanned by the plan node, reflecting the estimated selectivity of any `WHERE` clause conditions. Ideally, the estimate for the topmost node approximates the number of rows that the query actually returns, updates, or deletes.

- **width** —The total bytes of all the rows that this plan node outputs.

Note the following:

- The cost of a node includes the cost of its child nodes. The topmost plan node has the estimated total execution cost for the plan. This is the number the optimizer intends to minimize.
- The cost reflects only the aspects of plan execution that the query optimizer takes into consideration. For example, the cost does not reflect time spent transmitting result rows to the client.

EXPLAIN Example

The following example describes how to read an `EXPLAIN` query plan for a query:

```
EXPLAIN SELECT * FROM names WHERE name = 'Joelle';
                     QUERY PLAN
-------------------------------------------------------------
Gather Motion 2:1 (slice1) (cost=0.00..20.88 rows=1 width=13)

   -> Seq Scan on 'names' (cost=0.00..20.88 rows=1 width=13)
         Filter: name::text ~~ 'Joelle'::text
```

Read the plan from the bottom to the top. To start, the query optimizer sequentially scans the *names* table. Notice the `WHERE` clause is applied as a *filter* condition. This means the scan operation checks the condition for each row it scans and outputs only the rows that satisfy the condition.

The results of the scan operation are passed to a *gather motion* operation. In WarehousePG, a gather motion is when segments send rows to the coordinator. In this example, we have two segment instances that send to one coordinator instance. This operation is working on `slice1` of the parallel query execution plan. A query plan is divided into *slices* so the segments can work on portions of the query plan in parallel.

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The estimated startup cost for this plan is `00.00` (no cost) and a total cost of `20.88` disk page fetches. The optimizer estimates this query will return one row.

Reading EXPLAIN ANALYZE Output

`EXPLAIN ANALYZE` plans and runs the statement. The `EXPLAIN ANALYZE` plan shows the actual execution cost along with the optimizer's estimates. This allows you to see if the optimizer's estimates are close to reality. `EXPLAIN ANALYZE` also shows the following:

- The total runtime (in milliseconds) in which the query ran.
- The memory used by each slice of the query plan, as well as the memory reserved for the whole query statement.
- The number of *workers* (segments) involved in a plan node operation. Only segments that return rows are counted.
- The maximum number of rows returned by the segment that produced the most rows for the operation. If multiple segments produce an equal number of rows, `EXPLAIN ANALYZE` shows the segment with the longest *<time> to end*.
- The segment id of the segment that produced the most rows for an operation.
- For relevant operations, the amount of memory (`work_mem`) used by the operation. If the `work_mem` was insufficient to perform the operation in memory, the plan shows the amount of data spilled to disk for the lowest-performing segment. For example:

  ```
  Work_mem used: 64K bytes avg, 64K bytes max (seg0).
  Work_mem wanted: 90K bytes avg, 90K byes max (seg0) to lessen
  workfile I/O affecting 2 workers.
  ```

- The time (in milliseconds) in which the segment that produced the most rows retrieved the first row, and the time taken for that segment to retrieve all rows. The result may omit*<time> to first row* if it is the same as the *<time> to end*.

EXPLAIN ANALYZE Examples

This example describes how to read an `EXPLAIN ANALYZE` query plan using the same query. The `bold` parts of the plan show actual timing and rows returned for each plan node, as well as memory and time statistics for the whole query.

```
EXPLAIN ANALYZE SELECT * FROM names WHERE name = 'Joelle';
                     QUERY PLAN
-------------------------------------------------------------
Gather Motion 2:1 (slice1; segments: 2) (cost=0.00..20.88 rows=1 width=13)
    Rows out: 1 rows at destination with 0.305 ms to first row, 0.537 ms to end, start offset by 0.289 ms.
        -> Seq Scan on names (cost=0.00..20.88 rows=1 width=13)
             Rows out: Avg 1 rows x 2 workers. Max 1 rows (seg0) with 0.255 ms to first row, 0.486 ms to end, start offset by 0.968 ms.
                 Filter: name = 'Joelle'::text
 Slice statistics:

      (slice0) Executor memory: 135K bytes.

    (slice1) Executor memory: 151K bytes avg x 2 workers, 151K bytes max (seg0).

Statement statistics:
 Memory used: 128000K bytes
 Total runtime: 22.548 ms
```

Read the plan from the bottom to the top. The total elapsed time to run this query was *22.548* milliseconds.

The *sequential scan* operation had only one segment (*seg0*) that returned rows, and it returned just *1 row.* It took *0.255* milliseconds to find the first row and *0.486* to scan all rows. This result is close to the optimizer's estimate: the query optimizer estimated it would return one row for this query. The *gather motion* (segments sending data to the coordinator) received 1 row . The total elapsed time for this operation was *0.537* milliseconds.

Determining the Query Optimizer

You can view EXPLAIN output to determine if GPORCA is enabled for the query plan and whether GPORCA or the Postgres-based planner generated the explain plan. The information appears at the end of the EXPLAIN output. The `Settings` line displays the setting of the server configuration parameter `OPTIMIZER`. The `Optimizer:` line displays whether GPORCA or the Postgres-based planner generated the explain plan.

For these two example query plans, GPORCA is enabled, the server configuration parameter `OPTIMIZER` is `on`. For the first plan, GPORCA generated the EXPLAIN plan. For the second plan, WarehousePG fell back to the Postgres-based planner to generate the query plan.

```
                     QUERY PLAN
------------------------------------------------------------------------------
 Aggregate  (cost=0.00..296.14 rows=1 width=8)
   ->  Gather Motion 2:1  (slice1; segments: 2)  (cost=0.00..295.10 rows=1 width=8)
         ->  Aggregate  (cost=0.00..294.10 rows=1 width=8)
               ->  Seq Scan on part  (cost=0.00..97.69 rows=100040 width=1)
 Settings:  optimizer=on
 Optimizer: GPORCA
(5 rows)
```

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```
explain select count(*) from part;

                      QUERY PLAN
-----------------------------------------------------------------------------------------
 Aggregate  (cost=3519.05..3519.06 rows=1 width=8)
   ->  Gather Motion 2:1  (slice1; segments: 2)  (cost=3518.99..3519.03 rows=1 width=8)
         ->  Aggregate  (cost=3518.99..3519.00 rows=1 width=8)
               ->  Seq Scan on part  (cost=0.00..3018.79 rows=100040 width=1)
 Settings:  optimizer=on
 Optimizer: Postgres-based planner
(5 rows)
```

For this query, the server configuration parameter `OPTIMIZER` is `off`.

```
explain select count(*) from part;

                      QUERY PLAN
-----------------------------------------------------------------------------------------
 Aggregate  (cost=3519.05..3519.06 rows=1 width=8)
   ->  Gather Motion 2:1  (slice1; segments: 2)  (cost=3518.99..3519.03 rows=1 width=8)
         ->  Aggregate  (cost=3518.99..3519.00 rows=1 width=8)
               ->  Seq Scan on part  (cost=0.00..3018.79 rows=100040 width=1)
 Settings: optimizer=off
 Optimizer: Postgres-based planner
(5 rows)
```

Examining Query Plans to Solve Problems

If a query performs poorly, examine its query plan and ask the following questions:

- **Do operations in the plan take an exceptionally long time?** Look for an operation consumes the majority of query processing time. For example, if an index scan takes longer than expected, the index could be out-of-date and need to be reindexed. Or, adjust `enable_<operator>` parameters to see if you can force the Postgres-based planner to choose a different plan by deactivating a particular query plan operator for that query.
- **Does the query planning time exceed query execution time?** When the query involves many table joins, the Postgres-based planner uses a dynamic algorithm to plan the query that is in part based on the number of table joins. You can reduce the amount of time that the Postgres-based planner spends planning the query by setting the `join_collapse_limit` and `from_collapse_limit` server configuration parameters to a smaller value, such as `8`. Note that while smaller values reduce planning time, they may also yield inferior query plans.
- **Are the optimizer's estimates close to reality?** Run `EXPLAIN ANALYZE` and see if the number of rows the optimizer estimates is close to the number of rows the query operation actually returns. If there is a large discrepancy, collect more statistics on the relevant columns.

  See the *WarehousePG Reference Guide* for more information on the `EXPLAIN ANALYZE` and `ANALYZE` commands.
- **Are selective predicates applied early in the plan?** Apply the most selective filters early in the plan so fewer rows move up the plan tree. If the query plan does not correctly estimate query predicate selectivity, collect more statistics on the relevant columns. See the `ANALYZE` command in the *WarehousePG Reference Guide* for more information collecting statistics.You can also try reordering the `WHERE` clause of your SQL statement.
- **Does the optimizer choose the best join order?** When you have a query that joins multiple tables, make sure that the optimizer chooses the most selective join order. Joins that eliminate the largest number of rows should be done earlier in the plan so fewer rows move up the plan tree.

  If the plan is not choosing the optimal join order, set `join_collapse_limit=1` and use explicit `JOIN` syntax in your SQL statement to force the Postgres-based planner to the specified join order. You can also collect more statistics on the relevant join columns.

  See the `ANALYZE` command in the *WarehousePG Reference Guide* for more information collecting statistics.
- **Does the optimizer selectively scan partitioned tables?** If you use table partitioning, is the optimizer selectively scanning only the child tables required to satisfy the query predicates? Scans of the parent tables should return 0 rows since the parent tables do not contain any data. See Verifying the Partition Strategy for an example of a query plan that shows a selective partition scan.
- **Does the optimizer choose hash aggregate and hash join operations where applicable?** Hash operations are typically much faster than other types of joins or aggregations. Row comparison and sorting is done in memory rather than reading/writing from disk. To enable the query optimizer to choose hash operations, there must be sufficient memory available to hold the estimated number of rows. Try increasing work memory to improve performance for a query. If possible, run an `EXPLAIN ANALYZE` for the query to show which plan operations spilled to disk, how much work memory they used, and how much memory was required to avoid spilling to disk. For example:

  `Work_mem used: 23430K bytes avg, 23430K bytes max (seg0). Work_mem wanted: 33649K bytes avg, 33649K bytes max (seg0) to lessen workfile I/O affecting 2 workers.`

  The "bytes wanted" message from `EXPLAIN ANALYZE` is based on the amount of data written to work files and is not exact. The minimum `work_mem` needed can differ from the suggested value.

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4.6.12 Just-in-Time Compilation (JIT)

This topic provides an explanation of what Just-in-Time compilation is and how to configure it in WarehousePG.

Parent topic: SQL: Querying Data

What is JIT compilation?

Just-in-Time (JIT) compilation is the process of turning some form of interpreted program evaluation into a native program, and doing so at run time. For example, instead of using general-purpose code that can evaluate arbitrary SQL expressiones to evaluate a particular SQL predicate like `WHERE a.col=3`, it is possible to generate a function that is specific to that expression and can be natively executed by the CPU, resulting in faster execution.

WarehousePG uses LLVM for JIT compilation and it is enabled with all RPM distributions of WarehousePG. If you build WarehousePG from source, you must include the `--with-llvm` build option to include JIT compilation support.

It is possible to use JIT with both GPORCA and Postgres-based planner. Since GPORCA and Postgres-based planner use different algorithms and the values for the calculated costs are different, you must tune the JIT thresholds according to your usage. See When to JIT? for more information.

JIT accelerated operations

Currently WarehousePG's JIT implementation supports for accelerating expression evaluation and tuple deforming.

Expression evaluation is used to evaluate `WHERE` clauses, target lists, aggregates and projections. It can be accelerated by generating code specific to each case.

Tuple deforming is the process of transforming an on-disk tuple into its in-memory representation. It can be accelerated by creating a function specific to the table layout and the number of columns to be extracted.

In-line compilation (inlining)

WarehousePG is very extensible and allows new data types, functions, operators and other database objects to be defined. In fact, the built-in objects are implemented using nearly the same mechanisms. This extensibility implies some overhead, for example due to function calls. To reduce that overhead, JIT can use in-line compilation to fit the bodies of small functions into the expressions using them. That allows a significant percentage of the overhead to be optimized away.

Optimization

LLVM has support for optimizing generated code. Some of the optimizations are cheap enough to be performed whenever JIT is used, while others are only beneficial for longer-running queries. See the LLVM Documentation for more details about optimizations.

When to JIT?

JIT compilation is beneficial primarily for long-running CPU-bound queries. Frequently these are analytical queries. For short queries the added overhead of performing JIT compilation will often be higher than the time it can save.

> **Note** In order to use JIT, you must first install the LLVM libraries in your system by running the command `yum install llvm-libs`.

The internal workflow of JIT can be divided into three different stages:

1. Planner Stage

   This stage takes place in the WarehousePG coordinator. The planner generates the plan tree of a query and its estimated cost. By default, WarehousePG uses GPORCA to generate a query plan. Otherwise it uses Postgres-based planner as a fallback method.

   The planner decides to trigger JIT compilation if:

   - The server configuration parameter jit is `true`.
   - The estimated cost of the query is higher than the value of the configuration parameter optimizer_jit_above_cost (or jit_above_cost for Postgres-based planner).

   If the parameter jit_expressions is enabled, the planner suggests to the executor to compile the expressions in JIT space. Additionally, the planner must make other decisions; if the estimated cost is more than the setting of optimizer_jit_inline_above_cost (or jit_inline_above_cost for Postgres-based planner), the planner compiles short functions and operators used in the query using in-line compilation. If the estimated cost is more than the setting of optimizer_jit_optimize_above_cost (or jit_optimize_above_cost for Postgres-based planner), it applies expensive optimizations to improve the generated code. If the configuration parameterjit_tuple_deforming is enabled, it generates a custom function to deform the target table. Each of these options increases the JIT compilation overhead, but can reduce query execution time considerably.

   Verify the values of these configuration parameters for both GPORCA and Postgres-based planner, as the meaning of cost is different. When using GPORCA, WarehousePG may sometimes fall back to Postgres-based planner for some operations. Note that setting the JIT cost parameters to '0' forces all queries to be JIT-compiled and, as a result, slows down queries. Setting them to a negative value will disable the feature the parameter provides.

   When the plan is ready, the planner provides the plan trees and JIT flags to the executor.

2. Executor Initialization Stage

   This stage takes place in the WarehousePG segments. WarehousePG creates the expression evaluation steps. If JIT is used, it re-writes the steps as functions in the JIT space. The decisions made at plan time determine whether or not JIT compilation is adviced to be triggered in execution stage, along with the JIT strategy to apply if it is triggered. However, it is at execution time when WarehousePG makes the decision of using JIT if the configuration parameter `jit` is enabled and the JIT libraries are loaded successfully. The executor may ignore the cached decisions if `jit` or `jit_expression` has been changed to `false` between planner and execution stages or if it encounters an error.

   Additionally, the executor checks the following developer configuration parameters:

   - jit_provider : Specifies the name of the JIT provider library to be used.
   - jit_dump_bitcode: Writes the generated LLVM IR out to the file system, inside data_directory.
   - jit_profiling_support: If LLVM has the required functionality, emits the data needed to allow `perf` command to profile functions generated by JIT.
   - jit_debugging_support: If LLVM has the required functionality, registers generated functions with GDB.

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3. Executor Run Stage

   This stage also occurs in the WarehousePG segments which execute the steps provided by the initialization stage. The functions in JIT space are combined as a whole before the first call.

The JIT workflow can also handle executor fault tolerance: if JIT fails to load on the segments, the execution mode fails back to non-JIT.

Examples

In the examples below, the configuration parameter `optimizer_jit_above_cost` / `jit_above_cost` was modified so it would trigger JIT compilation. Note that the use of JIT might add more overhead than the potential savings. JIT was used, but inlining and expensive optimization were not. If `optimizer_jit_inline_above_cost` / `jit_inline_above_cost` or `optimizer_jit_optimize_above_cost` / `jit_optimize_above_cost` were also lowered, they could be triggered.

You may enable the configuration parameter gp_explain_jit to display summarized JIT information from all query executions when running the `EXPLAIN` command. You must turn it off when running regression tests.

Note that the output from `EXPLAIN` provides information on JIT such as the slice average timing spent in JIT, what segment the maximum vector comes from, or how many JIT functions are created and total time spent in JIT tasks. This information can be helpful when tuning JIT or debugging a timing problem. Run `EXPLAIN (ANALYZE, VERBOSE)` to view this information.

With GPORCA:

```
EXPLAIN (ANALYZE) SELECT * FROM jit_explain_output LIMIT 10;
QUERY PLAN
Limit  (cost=0.00..431.00 rows=1 width=4) (actual time=1.103..1.107 rows=10 loops=1)
  ->  Gather Motion 3:1  (slice1; segments: 3)  (cost=0.00..431.00 rows=1 width=4) (actual time=0.013..0.014 rows=10 loops=1)
        ->  Seq Scan on jit_explain_output  (cost=0.00..431.00 rows=1 width=4) (actual time=0.025..0.030 rows=38 loops=1)
Optimizer: GPORCA
Planning Time: 5.824 ms
  (slice0)    Executor memory: 37K bytes.
  (slice1)    Executor memory: 36K bytes avg x 3 workers, 36K bytes max (seg0).
Memory used:  128000kB
JIT:
  Options: Inlining false, Optimization false, Expressions true, Deforming true.
  (slice0): Functions: 2.00. Timing: 1.137 ms total.
Execution Time: 1.597 ms
(12 rows)
```

With Postgres-based planner:

```
EXPLAIN (ANALYZE) SELECT * FROM jit_explain_output LIMIT 10;
QUERY PLAN
Limit  (cost=35.50..35.67 rows=10 width=4) (actual time=13.199..13.310 rows=10 loops=1)
  ->  Gather Motion 3:1  (slice1; segments: 3)  (cost=35.50..36.01 rows=30 width=4) (actual time=11.848..11.890 rows=10 loops=1)
        ->  Limit  (cost=35.50..35.61 rows=10 width=4) (actual time=0.861..0.971 rows=10 loops=1)
              ->  Seq Scan on jit_explain_output  (cost=0.00..355.00 rows=32100 width=4) (actual time=0.029..0.070 rows=10 loops=1)
Optimizer: Postgres-based planner
Planning Time: 0.158 ms
  (slice0)    Executor memory: 37K bytes.
  (slice1)    Executor memory: 36K bytes avg x 3 workers, 36K bytes max (seg0).
Memory used:  128000kB
JIT:
  Options: Inlining false, Optimization false, Expressions true, Deforming true.
  (slice0): Functions: 2.00. Timing: 1.381 ms total.
  (slice1): Functions: 1.00 avg x 3 workers, 1.00 max (seg0). Timing: 0.830 ms avg x 3 workers, 0.854 ms max (seg1).
Execution Time: 24.023 ms
(14 rows)
```

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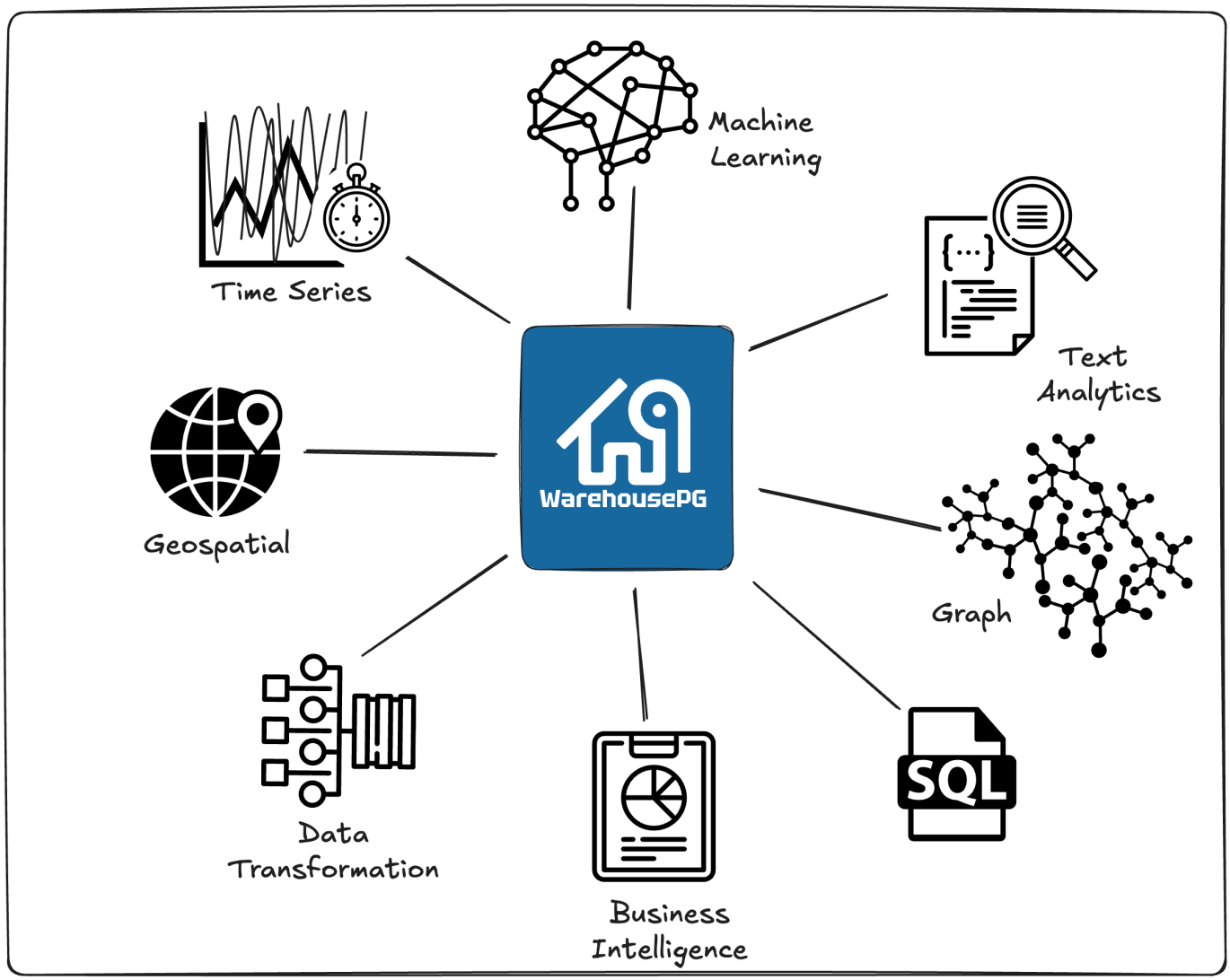
4.7 Overview of WarehousePG integrated analytics

WarehousePG offers a unique combination of a powerful, massively parallel processing (MPP) database and advanced data analytics. This combination creates an ideal framework for data scientists, data architects and business decision makers to explore artificial intelligence (AI), machine learning, deep learning, text analytics, and geospatial analytics.

The WarehousePG Integrated Analytics Ecosystem



The following WarehousePG analytics extensions are explored in different documentation sections, with installation and usage instructions:

Machine Learning and Deep Learning

The Apache MADlib extension allows WarehousePG users to run different machine learning and deep learning functions, including feature engineering, model training, evaluation and scoring.

Geospatial Analytics

PostGIS is a spatial database extension for PostgreSQL that allows GIS (Geographic Information Systems) objects to be stored in the database. The WarehousePG PostGIS extension includes support for GiST-based R-Tree spatial indexes and functions for analysis and processing of GIS objects.

Text Analytics

Text Analytics and Search enables processing of mass quantities of raw text data (such as social media feeds or e-mail databases) into mission-critical information that guides project and business decisions.

Programming Language Extensions

WarehousePG supports a variety of procedural languages that you can use for programming database analytics. Refer to the linked documentation for installation and usage instructions.

- PL/Java
- PL/Perl
- PL/pgSQL
- PL/Python
- PL/R

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Advanced Analytics and WarehousePG

The importance of advanced analytics in its various forms is growing rapidly in enterprise computing. Key enterprise data typically resides in relational and document form and it is inefficient to copy data between systems to perform analytical operations. WarehousePG is able to run both traditional and advanced analytics workloads in-database. This integrated capability greatly reduces the cost and the silos created by procuring and maintaining multiple tools and libraries.

WarehousePG advanced analytics can be used to address a wide variety of problems in many verticals including automotive, finance, manufacturing, energy, government, education, telecommunications, on-line and traditional retail.

The WarehousePG analytics capabilities allow you to:

- Analyze a multitude of data types – structured, text, geospatial, and graph – in a single environment, which can scale to petabytes and run algorithms designed for parallelism.
- Leverage existing SQL knowledge: WarehousePG can run dozens of statistical, machine learning, and graph methods, via SQL.
- Train more models in less time by taking advantage of the parallelism in the MPP architecture and in-database analytics.
- Access the data where it lives, therefore integrate data and analytics in one place. WarehousePG is infrastructure-agnostic and runs on bare metal, private cloud, and public cloud deployments.
- Use a multitude of data extensions. WarehousePG supports extensions for HDFS, Hive, and HBase as well as reading/writing data from/to cloud storage, including Amazon S3 objects. Review the capabilities of the WarehousePG Platform Extension Framework (PXF), which provides *connectors* that enable you to access data stored in sources external to your WarehousePG deployment.
- Use familiar and leading BI and advanced analytics software that are ODBC/JDBC compatible, or have native integrations, including SAS, IBM Cognos, SAP Analytics Solutions, Qlik, Tableau, Apache Zeppelin, and Jupyter.
- Run deep learning algorithms using popular frameworks like Keras and TensorFlow in an MPP relational database, with GPU (Graphical Processing Unit) acceleration.
- Use containers capable of isolating executors from the host OS. WarehousePG PL/Container implements a trusted language execution engine which permits customized data science workloads or environments created for different end user workloads.
- Use procedural languages to customize your analytics. WarehousePG supports development in R, Python, Java, and other standard languages allowing you to distribute execution across the entire cluster to take advantage of the scale and parallelism.

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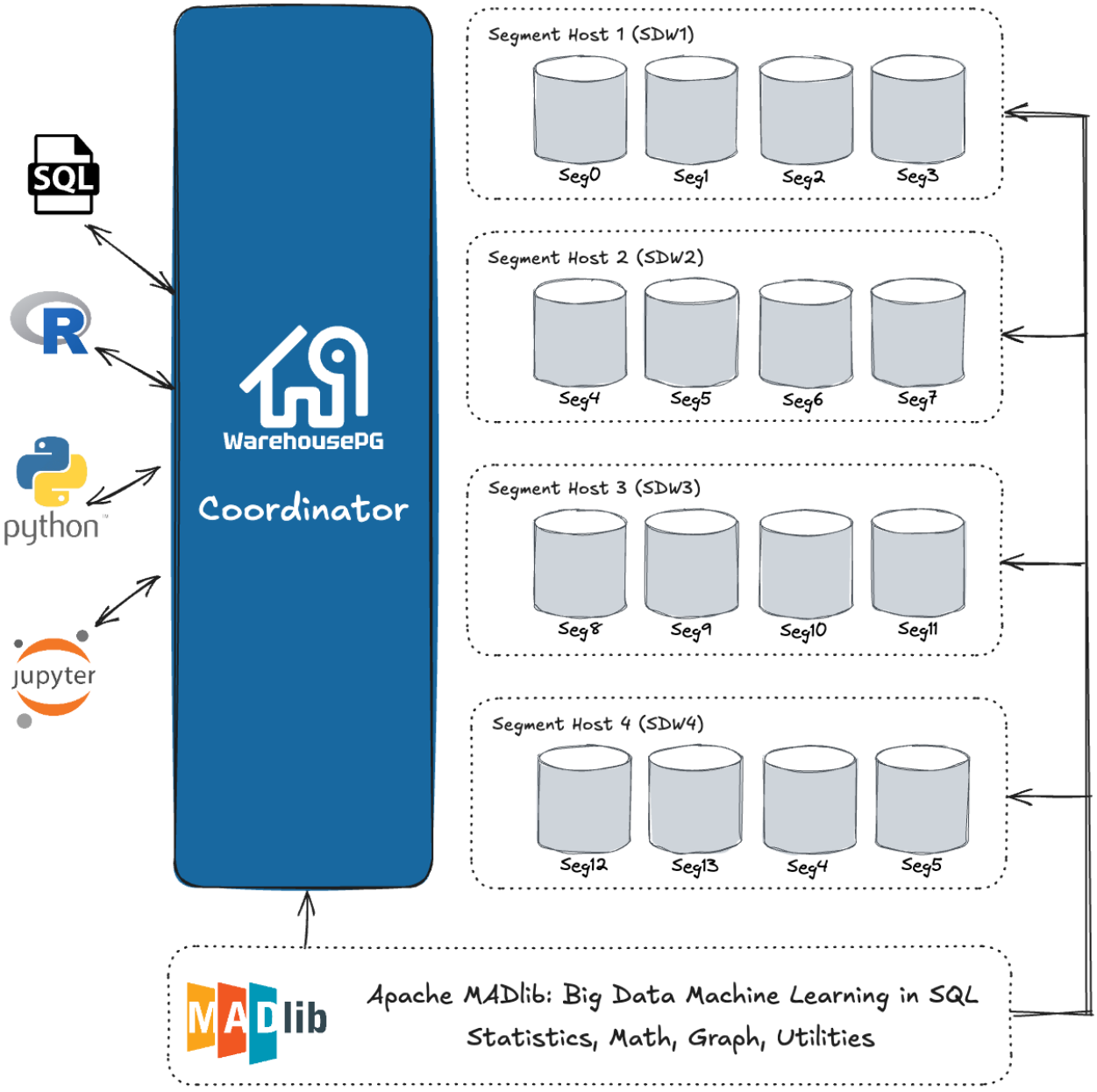
4.7.1 Machine Learning and Deep Learning using MADlib

Apache MADlib is an open-source library for scalable in-database analytics. The WarehousePG MADlib extension provides the ability to run machine learning and deep learning workloads in a WarehousePG.

You can install it as an extension in a WarehousePG cluster you can run data-parallel implementations of mathematical, statistical, graph, machine learning, and deep learning methods on structured and unstructured data. For WarehousePG and MADlib version compatibility, refer to MADlib FAQ.

MADlib's suite of SQL-based algorithms run at scale within a single WarehousePG engine without needing to transfer data between the database and other tools.

MADlib is part of the database fabric with no changes to the WarehousePG architecture. This makes it easy for database administrators to deploy and manage since it is not a separate daemon or separate software running outside the database.



Machine Learning

Apache MADlib consists of methods to support the full spectrum of data science activities. This includes data transformation and feature engineering, using methods in descriptive and inferential statistics, pivoting, sessionization and encoding categorical variables. There is also a comprehensive library of graph, supervised learning and unsupervised learning methods.

In the area of model selection, MADlib supports cross validation and the most common prediction metrics for evaluating the quality of predictions of a model. Please refer to theMADlib user guide for more information on these methods.

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Deep Learning

WarehousePG supports using Keras and TensorFlow for deep learning. You can review the supported libraries and configuration instructions on the Apache MADlib pages as well as user documentation for Keras API using the Tensorflow backend.

MADlib supports Keras with a TensorFlow backend, with or without Graphics Processing Units (GPUs). GPUs can significantly accelerate the training of deep neural networks so they are typically used for enterprise level workloads. For further GPU information, visit the MADlib wiki, https://cwiki.apache.org/confluence/display/MADLIB/Deep+Learning.

PivotalR

MADlib can be used with PivotalR, an R client package that enables users to interact with data resident in the WarehousePG. PivotalR can be considered as a wrapper around MADlib that translates R code into SQL to run on MPP databases and is designed for users familiar with R but with data sets that are too large for R.

The R language is an open-source language that is used for statistical computing. PivotalR is an R package that enables users to interact with data resident in WarehousePG using the R client. Using PivotalR requires that MADlib is installed on the WarehousePG.

PivotalR allows R users to leverage the scalability and performance of in-database analytics without leaving the R command line. The computational work is run in-database, while the end user benefits from the familiar R interface. Compared with respective native R functions, there is an increase in scalability and a decrease in running time. Furthermore, data movement, which can take hours for very large data sets, is eliminated with PivotalR.

Key features of the PivotalR package:

- Explore and manipulate data in the database with R syntax. SQL translation is performed by PivotalR.
- Use the familiar R syntax for predictive analytics algorithms, for example linear and logistic regression. PivotalR accesses the MADlib in-database analytics function calls.
- Comprehensive documentation package with examples in standard R format accessible from an R client.
- The PivotalR package also supports access to the MADlib functionality.

For information about PivotalR, including supported MADlib functionality, see https://cwiki.apache.org/confluence/display/MADLIB/PivotalR.

The R package for PivotalR can be found at https://cran.r-project.org/web/packages/PivotalR/index.html.

Prerequisites

MADlib requires the `m4` macro processor version 1.4.13 or later. Ensure that you have access to, or superuser permissions to install, this package on each WarehousePG host.

MADlib 2.1.0 requires Python 3, which should already be installed as a dependency when you install the WarehousePG software on each WarehousePG host.

Installing MADlib

To install MADlib on WarehousePG, you first install a compatible WarehousePG MADlib package and then install the MADlib function libraries on all databases that will use MADlib.

If you have GPUs installed on some or across all hosts in the cluster, then the segments residing on those hosts can benefit from GPU acceleration. GPUs and deep learning libraries such as Keras, TensorFlow, cudNN, and CUDA are managed separately from MADlib. For more information see the MADlib wiki instructions for deep learning and the MADlib user documentation for deep learning .

Installing the WarehousePG MADlib Package

Before you install the MADlib package, make sure that your WarehousePG is running, you have sourced `greenplum_path.sh` , and that the `$COORDINATOR_DATA_DIRECTORY` and `$GPHOME` variables are set.

1. Download the MADlib extension package.
2. Copy the MADlib package to the WarehousePG coordinator host.
3. Unpack the MADlib distribution package. For example:

   ```
   $ tar xzvf madlib-2.1.0-gp7-rhel8-x86_64.tar.gz
   ```

4. Install the software package

Adding MADlib Functions to a Database

After installing the MADlib package, run the `madpack` command to add MADlib functions to WarehousePG. `madpack` is in `$GPHOME/madlib/bin` .

```
$ madpack [-s <schema_name>] -p greenplum -c <user>@<host>:<port>/<database> install
```

For example, this command creates MADlib functions in the WarehousePG `testdb` running on server `cdw` on port `5432` . The `madpack` command logs in as the user `gpadmin` and prompts for password. The target schema is `madlib` .

```
$ madpack -s madlib -p greenplum -c gpadmin@cdw:5432/testdb install
```

After installing the functions, The WarehousePG `gpadmin` superuser role should grant all privileges on the target schema (in the example `madlib`) to users who will be accessing MADlib functions. Users without access to the functions will get the error `ERROR: permission denied for schema MADlib` .

The madpack `install-check` option runs test using Madlib modules to check the MADlib installation:

```
$ madpack -s madlib -p greenplum -c gpadmin@cdw:5432/testdb install-check
```

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> **Note** The command `madpack -h` displays information for the utility.

Uninstalling MADlib

When you remove MADlib support from a database, routines that you created in the database that use MADlib functionality will no longer work.

Examples

Following are examples using the WarehousePG MADlib extension:

- Linear Regression
- Association Rules
- Naive Bayes Classification

See the MADlib documentation for additional examples.

Linear Regression

This example runs a linear regression on the table `regr_example`. The dependent variable data are in the `y` column and the independent variable data are in the `x1` and `x2` columns.

The following statements create the `regr_example` table and load some sample data:

```
DROP TABLE IF EXISTS regr_example;
CREATE TABLE regr_example (
   id int,
   y int,
   x1 int,
   x2 int
);
INSERT INTO regr_example VALUES
   (1,  5, 2, 3),
   (2, 10, 7, 2),
   (3,  6, 4, 1),
   (4,  8, 3, 4);
```

The MADlib `linregr_train()` function produces a regression model from an input table containing training data. The following `SELECT` statement runs a simple multivariate regression on the `regr_example` table and saves the model in the `reg_example_model` table.

```
SELECT madlib.linregr_train (
   'regr_example',         -- source table
   'regr_example_model',   -- output model table
   'y',                    -- dependent variable
   'ARRAY[1, x1, x2]'      -- independent variables
);
```

The `madlib.linregr_train()` function can have additional arguments to set grouping columns and to calculate the heteroskedasticity of the model.

> **Note** The intercept is computed by setting one of the independent variables to a constant `1`, as shown in the preceding example.

Running this query against the `regr_example` table creates the `regr_example_model` table with one row of data:

```
SELECT * FROM regr_example_model;
-[ RECORD 1 ]------------+------------------------
coef                     | {0.111111111111127,1.14814814814815,1.01851851851852}
r2                       | 0.968612680477111
std_err                  | {1.49587911309236,0.207043331249903,0.346449758034495}
t_stats                  | {0.0742781352708591,5.54544858420156,2.93987366103776}
p_values                 | {0.952799748147436,0.113579771006374,0.208730790695278}
condition_no             | 22.650203241881
num_rows_processed       | 4
num_missing_rows_skipped | 0
variance_covariance      | {{2.23765432098598,-0.257201646090342,-0.437242798353582},
                           {-0.257201646090342,0.042866941015057,0.0342935528120456},
                           {-0.437242798353582,0.0342935528120457,0.120027434842l6}}
```

The model saved in the `regr_example_model` table can be used with the MADlib linear regression prediction function, `madlib.linregr_predict()`, to view the residuals:

```
SELECT regr_example.*,
       madlib.linregr_predict ( ARRAY[1, x1, x2], m.coef ) as predict,
       y - madlib.linregr_predict ( ARRAY[1, x1, x2], m.coef ) as residual
FROM regr_example, regr_example_model m;
 id | y  | x1 | x2 |     predict      |      residual
----+----+----+----+------------------+--------------------
  1 |  5 |  2 |  3 | 5.46296296296297 | -0.462962962962971
  3 |  6 |  4 |  1 | 5.72222222222224 |  0.277777777777762
  2 | 10 |  7 |  2 | 10.1851851851852 | -0.185185185185201
  4 |  8 |  3 |  4 | 7.62962962962964 |  0.370370370370364
(4 rows)
```

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Association Rules

This example demonstrates the association rules data mining technique on a transactional data set. Association rule mining is a technique for discovering relationships between variables in a large data set. This example considers items in a store that are commonly purchased together. In addition to market basket analysis, association rules are also used in bioinformatics, web analytics, and other fields.

The example analyzes purchase information for seven transactions that are stored in a table with the MADlib function `MADlib.assoc_rules`. The function assumes that the data is stored in two columns with a single item and transaction ID per row. Transactions with multiple items consist of multiple rows with one row per item.

These commands create the table.

```
DROP TABLE IF EXISTS test_data;
CREATE TABLE test_data (
   trans_id INT,
   product text
);
```

This `INSERT` command adds the data to the table.

```
INSERT INTO test_data VALUES
   (1, 'beer'),
   (1, 'diapers'),
   (1, 'chips'),
   (2, 'beer'),
   (2, 'diapers'),
   (3, 'beer'),
   (3, 'diapers'),
   (4, 'beer'),
   (4, 'chips'),
   (5, 'beer'),
   (6, 'beer'),
   (6, 'diapers'),
   (6, 'chips'),
   (7, 'beer'),
   (7, 'diapers');
```

The MADlib function `madlib.assoc_rules()` analyzes the data and determines association rules with the following characteristics.

- A support value of at least .40. Support is the ratio of transactions that contain X to all transactions.
- A confidence value of at least .75. Confidence is the ratio of transactions that contain X to transactions that contain Y. One could view this metric as the conditional probability of X given Y.

This `SELECT` command determines association rules, creates the table `assoc_rules`, and adds the statistics to the table.

```
SELECT * FROM madlib.assoc_rules (
   .40,          -- support
   .75,          -- confidence
   'trans_id',   -- transaction column
   'product',    -- product purchased column
   'test_data',  -- table name
   'public',     -- schema name
   false);       -- display processing details
```

This is the output of the `SELECT` command. There are two rules that fit the characteristics.

```
 output_schema | output_table | total_rules | total_time
---------------+--------------+-------------+-----------------
public         | assoc_rules  |           2 | 00:00:01.153283
(1 row)
```

To view the association rules, you can run this `SELECT` command.

```
SELECT pre, post, support FROM assoc_rules
   ORDER BY support DESC;
```

This is the output. The `pre` and `post` columns are the itemsets of left and right hand sides of the association rule respectively.

```
    pre    |  post  |      support
-----------+--------+-------------------
 {diapers} | {beer} | 0.714285714285714
 {chips}   | {beer} | 0.428571428571429
(2 rows)
```

Based on the data, beer and diapers are often purchased together. To increase sales, you might consider placing beer and diapers closer together on the shelves.

Naive Bayes Classification

Naive Bayes analysis predicts the likelihood of an outcome of a class variable, or category, based on one or more independent variables, or attributes. The class variable is a non-numeric categorial variable, a variable that can have one of a limited number of values or categories. The class variable is represented with integers, each integer representing a category. For example, if the category can be one of "true", "false", or "unknown," the values can be represented with the integers 1, 2, or 3.

The attributes can be of numeric types and non-numeric, categorical, types. The training function has two signatures – one for the case where all attributes are numeric and another for mixed numeric and categorical types. Additional arguments for the latter identify the attributes that should be handled as numeric values. The attributes are submitted to the training function in an array.

The MADlib Naive Bayes training functions produce a features probabilities table and a class priors table, which can be used with the prediction function to provide the probability of a class for the set of attributes.

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Naive Bayes Example 1 - Simple All-numeric Attributes

In the first example, the `class` variable is either 1 or 2 and there are three integer attributes.

1. The following commands create the input table and load sample data.

```
DROP TABLE IF EXISTS class_example CASCADE;
CREATE TABLE class_example (
   id int, class int, attributes int[]);
INSERT INTO class_example VALUES
   (1, 1, '{1, 2, 3}'),
   (2, 1, '{1, 4, 3}'),
   (3, 2, '{0, 2, 2}'),
   (4, 1, '{1, 2, 1}'),
   (5, 2, '{1, 2, 2}'),
   (6, 2, '{0, 1, 3}');
```

   Actual data in production scenarios is more extensive than this example data and yields better results. Accuracy of classification improves significantly with larger training data sets.

2. Train the model with the `create_nb_prepared_data_tables()` function.

```
SELECT * FROM madlib.create_nb_prepared_data_tables (
   'class_example',         -- name of the training table
   'class',                 -- name of the class (dependent) column
   'attributes',            -- name of the attributes column
   3,                       -- the number of attributes
   'example_feature_probs', -- name for the feature probabilities output table
   'example_priors'         -- name for the class priors output table
    );
```

3. Create a table with data to classify using the model.

```
DROP TABLE IF EXISTS class_example_topredict;
CREATE TABLE class_example_topredict (
   id int, attributes int[]);
INSERT INTO class_example_topredict VALUES
   (1, '{1, 3, 2}'),
   (2, '{4, 2, 2}'),
   (3, '{2, 1, 1}');
```

4. Create a classification view using the feature probabilities, class priors, and `class_example_topredict` tables.

```
SELECT madlib.create_nb_probs_view (
   'example_feature_probs',    -- feature probabilities output table
   'example_priors',           -- class priors output table
   'class_example_topredict',  -- table with data to classify
   'id',                       -- name of the key column
   'attributes',               -- name of the attributes column
    3,                         -- number of attributes
    'example_classified'       -- name of the view to create
    );
```

5. Display the classification results.

```
SELECT * FROM example_classified;
 key | class | nb_prob
-----+-------+---------
   1 |     1 |     0.4
   1 |     2 |     0.6
   3 |     1 |     0.5
   3 |     2 |     0.5
   2 |     1 |    0.25
   2 |     2 |    0.75
(6 rows)
```

Naive Bayes Example 2 – Weather and Outdoor Sports

This example calculates the probability that the user will play an outdoor sport, such as golf or tennis, based on weather conditions.

The table `weather_example` contains the example values.

The identification column for the table is `day`, an integer type.

The `play` column holds the dependent variable and has two classifications:

- 0 - No
- 1 - Yes

There are four attributes: outlook, temperature, humidity, and wind. These are categorical variables. The MADlib `create_nb_classify_view()` function expects the attributes to be provided as an array of `INTEGER`, `NUMERIC`, or `FLOAT8` values, so the attributes for this example are encoded with integers as follows:

- *outlook* may be sunny (1), overcast (2), or rain (3).
- *temperature* may be hot (1), mild (2), or cool (3).
- *humidity* may be high (1) or normal (2).
- *wind* may be strong (1) or weak (2).

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The following table shows the training data, before encoding the variables.

```
 day | play | outlook  | temperature | humidity | wind
-----+------+----------+-------------+----------+--------
 2   | No   | Sunny    | Hot         | High     | Strong
 4   | Yes  | Rain     | Mild        | High     | Weak
 6   | No   | Rain     | Cool        | Normal   | Strong
 8   | No   | Sunny    | Mild        | High     | Weak
10   | Yes  | Rain     | Mild        | Normal   | Weak
12   | Yes  | Overcast | Mild        | High     | Strong
14   | No   | Rain     | Mild        | High     | Strong
 1   | No   | Sunny    | Hot         | High     | Weak
 3   | Yes  | Overcast | Hot         | High     | Weak
 5   | Yes  | Rain     | Cool        | Normal   | Weak
 7   | Yes  | Overcast | Cool        | Normal   | Strong
 9   | Yes  | Sunny    | Cool        | Normal   | Weak
11   | Yes  | Sunny    | Mild        | Normal   | Strong
13   | Yes  | Overcast | Hot         | Normal   | Weak
(14 rows)
```

1. Create the training table.

```
DROP TABLE IF EXISTS weather_example;
CREATE TABLE weather_example (
   day int,
   play int,
   attrs int[]
);
INSERT INTO weather_example VALUES
   ( 2, 0, '{1,1,1,1}'), -- sunny, hot, high, strong
   ( 4, 1, '{3,2,1,2}'), -- rain, mild, high, weak
   ( 6, 0, '{3,3,2,1}'), -- rain, cool, normal, strong
   ( 8, 0, '{1,2,1,2}'), -- sunny, mild, high, weak
   (10, 1, '{3,2,2,2}'), -- rain, mild, normal, weak
   (12, 1, '{2,2,1,1}'), -- etc.
   (14, 0, '{3,2,1,1}'),
   ( 1, 0, '{1,1,1,2}'),
   ( 3, 1, '{2,1,1,2}'),
   ( 5, 1, '{3,3,2,2}'),
   ( 7, 1, '{2,3,2,1}'),
   ( 9, 1, '{1,3,2,2}'),
   (11, 1, '{1,2,2,1}'),
   (13, 1, '{2,1,2,2}');
```

2. Create the model from the training table.

```
SELECT madlib.create_nb_prepared_data_tables (
   'weather_example',  -- training source table
   'play',             -- dependent class column
   'attrs',            -- attributes column
   4,                  -- number of attributes
   'weather_probs',    -- feature probabilities output table
   'weather_priors'    -- class priors
   );
```

3. View the feature probabilities:

```
SELECT * FROM weather_probs;
 class | attr | value | cnt | attr_cnt
-------+------+-------+-----+----------
     1 |    3 |     2 |   6 |        2
     1 |    1 |     2 |   4 |        3
     0 |    1 |     1 |   3 |        3
     0 |    1 |     3 |   2 |        3
     0 |    3 |     1 |   4 |        2
     1 |    4 |     1 |   3 |        2
     1 |    2 |     3 |   3 |        3
     1 |    2 |     1 |   2 |        3
     0 |    2 |     2 |   2 |        3
     0 |    4 |     2 |   2 |        2
     0 |    3 |     2 |   1 |        2
     0 |    1 |     2 |   0 |        3
     1 |    1 |     1 |   2 |        3
     1 |    1 |     3 |   3 |        3
     1 |    3 |     1 |   3 |        2
     0 |    4 |     1 |   3 |        2
     0 |    2 |     3 |   1 |        3
     0 |    2 |     1 |   2 |        3
     1 |    2 |     2 |   4 |        3
     1 |    4 |     2 |   6 |        2
(20 rows)
```

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4. To classify a group of records with a model, first load the data into a table. In this example, the table `t1` has four rows to classify.

```
DROP TABLE IF EXISTS t1;
CREATE TABLE t1 (
   id integer,
   attributes integer[]);
insert into t1 values
   (1, '{1, 2, 1, 1}'),
   (2, '{3, 3, 2, 1}'),
   (3, '{2, 1, 2, 2}'),
   (4, '{3, 1, 1, 2}');
```

5. Use the MADlib `create_nb_classify_view()` function to classify the rows in the table.

```
SELECT madlib.create_nb_classify_view (
   'weather_probs',      -- feature probabilities table
   'weather_priors',     -- classPriorsName
   't1',                 -- table containing values to classify
   'id',                 -- key column
   'attributes',         -- attributes column
   4,                    -- number of attributes
   't1_out'              -- output table name
);
```

The result is four rows, one for each record in the `t1` table.

```
SELECT * FROM t1_out ORDER BY key;
 key | nb_classification
-----+-------------------
 1 | {0}
 2 | {1}
 3 | {1}
 4 | {0}
 (4 rows)
```

References

MADlib web site is at http://madlib.apache.org/.

MADlib documentation is at http://madlib.apache.org/documentation.html.

PivotalR is a first class R package that enables users to interact with data resident in WarehousePG and MADLib using an R client.

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4.7.2 Graph Analytics

Many modern business problems involve connections and relationships between entities, and are not solely based on discrete data. Graphs are powerful at representing complex interconnections, and graph data modeling is very effective and flexible when the number and depth of relationships increase exponentially.

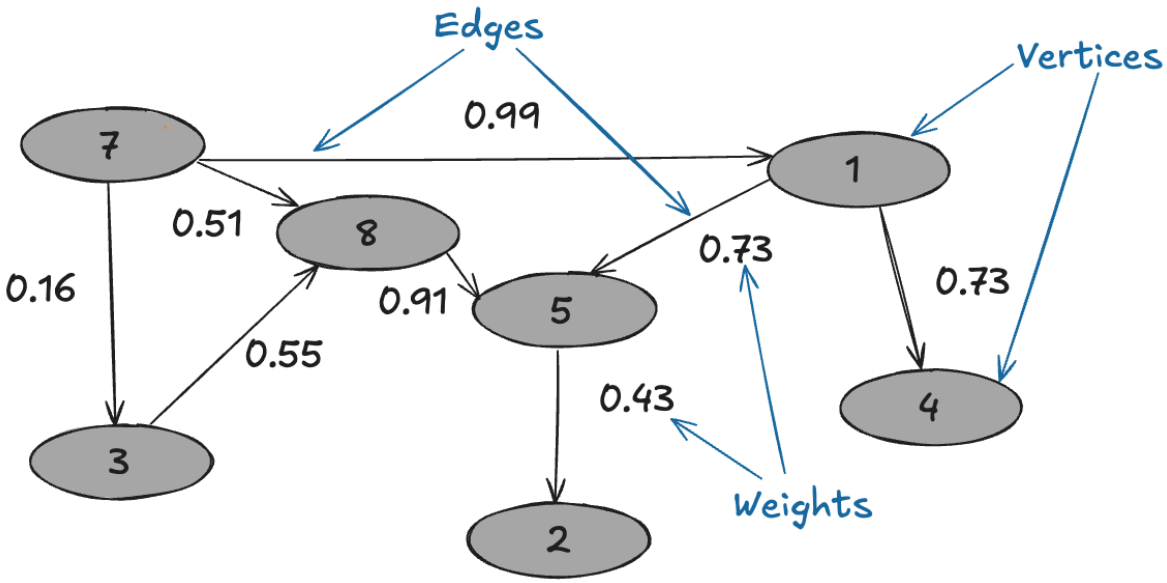
The use cases for graph analytics are diverse: social networks, transportation routes, autonomous vehicles, cyber security, criminal networks, fraud detection, health research, epidemiology, and so forth.

This chapter contains the following information:

- What is a Graph?
- Graph Analytics on WarehousePG
- Using Graph
- Graph Modules
- References

What is a Graph?

Graphs represent the interconnections between objects (vertices) and their relationships (edges). Example objects could be people, locations, cities, computers, or components on a circuit board. Example connections could be roads, circuits, cables, or interpersonal relationships. Edges can have directions and weights, for example the distance between towns.



Graphs can be small and easily traversed - as with a small group of friends - or extremely large and complex, similar to contacts in a modern-day social network.

Graph Analytics on WarehousePG

Efficient processing of very large graphs can be challenging. WarehousePG offers a suitable environment for this work for these key reasons:

1. Using MADlib graph functions in WarehousePG brings the graph computation close to where the data lives. Otherwise, large data sets need to be moved to a specialized graph database, requiring additional time and resources.
2. Specialized graph databases frequently use purpose-built languages. With WarehousePG, you can invoke graph functions using the familiar SQL interface. For example, for thePageRank graph algorithm:

```
SELECT madlib.pagerank('vertex',     -- Vertex table
              'id',                  -- Vertex id column
              'edge',                -- Edge table
              'src=src, dest=dest', -- Comma delimited string of edge arguments
              'pagerank_out',        -- Output table of PageRank
               0.5);                 -- Damping factor
SELECT * FROM pagerank_out ORDER BY pagerank DESC;
```

3. A lot of data science problems are solved using a combination of models, with graphs being just one. Regression, clustering, and other methods available in WarehousePG, make for a powerful combination.
4. WarehousePG offers great benefits of scale, taking advantage of years of query execution and optimization research focused on large data sets.

Using Graph

Installing Graph Modules

To use the MADlib graph modules, install the version of MADlib corresponding to your WarehousePG version.

Graph modules on MADlib support many algorithms.

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Creating a Graph in WarehousePG

To represent a graph in WarehousePG, create tables that represent the vertices, edges, and their properties.

Using SQL, create the relevant tables in the database you want to use. This example uses `testdb`:

```
gpadmin@cdw ~]$ psql
dev=# \c testdb
```

Create a table for vertices, called `vertex`, and a table for edges and their weights, called `edge`:

```
testdb=# DROP TABLE IF EXISTS vertex, edge;
testdb=# CREATE TABLE vertex(id INTEGER);
testdb=# CREATE TABLE edge(
         src INTEGER,
         dest INTEGER,
         weight FLOAT8
         );
```

Insert values related to your specific use case. For example :

```
testdb#=> INSERT INTO vertex VALUES
(0),
(1),
(2),
(3),
(4),
(5),
(6),
(7);

testdb#=> INSERT INTO edge VALUES
(0, 1, 1.0),
(0, 2, 1.0),
(0, 4, 10.0),
(1, 2, 2.0),
(1, 3, 10.0),
(2, 3, 1.0),
(2, 5, 1.0),
(2, 6, 3.0),
(3, 0, 1.0),
(4, 0, -2.0),
(5, 6, 1.0),
(6, 7, 1.0);
```

Now select the Graph Module that suits your analysis.

Graph Modules

This section lists the graph functions supported in MADlib. They include: All Pairs Shortest Path (APSP), Breadth-First Search, Hyperlink-Induced Topic Search (HITS), PageRank and Personalized PageRank, Single Source Shortest Path (SSSP), Weakly Connected Components, and Measures. Explore each algorithm using the example `edge` and `vertex` tables already created.

All Pairs Shortest Path (APSP)

The all pairs shortest paths (APSP) algorithm finds the length (summed weights) of the shortest paths between all pairs of vertices, such that the sum of the weights of the path edges is minimized.

The function is:

```
graph_apsp( vertex_table,
vertex_id,
edge_table,
edge_args,
out_table,
grouping_cols
)
```

For details on the parameters, with examples, see the All Pairs Shortest Path in the Apache MADlib documentation.

Breadth-First Search

Given a graph and a source vertex, the breadth-first search (BFS) algorithm finds all nodes reachable from the source vertex by searching / traversing the graph in a breadth-first manner.

The function is:

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```
graph_bfs( vertex_table,
          vertex_id,
          edge_table,
          edge_args,
          source_vertex,
          out_table,
          max_distance,
          directed,
          grouping_cols
          )
```

For details on the parameters, with examples, see the Breadth-First Search in the Apache MADlib documentation.

Hyperlink-Induced Topic Search (HITS)

The all pairs shortest paths (APSP) algorithm finds the length (summed weights) of the shortest paths between all pairs of vertices, such that the sum of the weights of the path edges is minimized.

The function is:

```
graph_apsp( vertex_table,
           vertex_id,
           edge_table,
           edge_args,
           out_table,
           grouping_cols
           )
```

For details on the parameters, with examples, see the Hyperlink-Induced Topic Search in the Apache MADlib documentation.

PageRank and Personalized PageRank

Given a graph, the PageRank algorithm outputs a probability distribution representing a person's likelihood to arrive at any particular vertex while randomly traversing the graph.

MADlib graph also includes a personalized PageRank, where a notion of importance provides personalization to a query. For example, importance scores can be biased according to a specified set of graph vertices that are of interest or special in some way.

The function is:

```
pagerank( vertex_table,
          vertex_id,
          edge_table,
          edge_args,
          out_table,
          damping_factor,
          max_iter,
          threshold,
          grouping_cols,
          personalization_vertices
          )
```

For details on the parameters, with examples, see the PageRank in the Apache MADlib documentation.

Single Source Shortest Path (SSSP)

Given a graph and a source vertex, the single source shortest path (SSSP) algorithm finds a path from the source vertex to every other vertex in the graph, such that the sum of the weights of the path edges is minimized.

The function is:

```
graph_sssp ( vertex_table,
vertex_id,
edge_table,
edge_args,
source_vertex,
out_table,
grouping_cols
)
```

For details on the parameters, with examples, see the Single Source Shortest Path in the Apache MADlib documentation.

Weakly Connected Components

Given a directed graph, a weakly connected component (WCC) is a subgraph of the original graph where all vertices are connected to each other by some path, ignoring the direction of edges.

The function is:

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```
weakly_connected_components(
vertex_table,
vertex_id,
edge_table,
edge_args,
out_table,
grouping_cols
)
```

For details on the parameters, with examples, see the Weakly Connected Components in the Apache MADlib documentation.

Measures

These algorithms relate to metrics computed on a graph and include: Average Path Length, Closeness Centrality , Graph Diameter, and In-Out Degree.

Average Path Length

This function computes the shortest path average between pairs of vertices. Average path length is based on "reachable target vertices", so it averages the path lengths in each connected component and ignores infinite-length paths between unconnected vertices. If the user requires the average path length of a particular component, the weakly connected components function may be used to isolate the relevant vertices.

The function is:

```
graph_avg_path_length( apsp_table,
                       output_table
                       )
```

This function uses a previously run APSP (All Pairs Shortest Path) output. For details on the parameters, with examples, see theAverage Path Length in the Apache MADlib documentation.

Closeness Centrality

The closeness centrality algorithm helps quantify how much information passes through a given vertex. The function returns various closeness centrality measures and the k-degree for a given subset of vertices.

The function is:

```
graph_closeness( apsp_table,
output_table,
vertex_filter_expr
)
```

This function uses a previously run APSP (All Pairs Shortest Path) output. For details on the parameters, with examples, see theCloseness in the Apache MADlib documentation.

Graph Diameter

Graph diameter is defined as the longest of all shortest paths in a graph. The function is:

```
graph_diameter( apsp_table,
output_table
)
```

This function uses a previously run APSP (All Pairs Shortest Path) output. For details on the parameters, with examples, see theGraph Diameter in the Apache MADlib documentation.

In-Out Degree

This function computes the degree of each node. The node degree is the number of edges adjacent to that node. The node in-degree is the number of edges pointing in to the node and node out-degree is the number of edges pointing out of the node.

The function is:

```
graph_vertex_degrees( vertex_table,
vertex_id,
edge_table,
edge_args,
out_table,
grouping_cols
)
```

For details on the parameters, with examples, see the In-out Degree page in the Apache MADlib documentation.

References

MADlib on WarehousePG is at Machine Learning and Deep Learning using MADlib.

MADlib Apache web site and MADlib release notes are at http://madlib.apache.org/.

MADlib user documentation is at http://madlib.apache.org/documentation.html.

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4.7.3 Geospatial Analytics

PostGIS is a spatial database extension for PostgreSQL that allows you to store GIS (Geographic Information Systems) objects in the database. The WarehousePG PostGIS extension supports some PostGIS optional extensions such as GiST-based R-Tree spatial indexes, and functions for analysis and processing of GIS objects. It also includes support for the PostGIS `raster` data type. With the PostGIS Raster objects, the PostGIS `geometry` data type offers a single set of overlay SQL functions (such as `ST_Intersects`) operating seamlessly on vector and raster geospatial data. PostGIS Raster uses the GDAL (Geospatial Data Abstraction Library) translator library for raster geospatial data formats that presents a single raster abstract data model to a calling application.

For information about WarehousePG PostGIS extension support, see PostGIS Extension Support and Limitations.

For information about PostGIS, see https://postgis.net/

For information about GDAL, see https://gdal.org/.

WarehousePG PostGIS Extension

WarehousePG supports the PostGIS extension with these component versions:

- PostGIS 3.3.2
- Proj 8.2.1
- Geos 3.10.2
- GDAL 3.6.3
- Json 0.12
- Expat 2.5.0

For information about the supported WarehousePG extension packages and software versions, see Extensions.

There are significant changes in PostGIS 3.3.2 compared with earlier versions. For a list of new and enhanced functions in PostGIS 3.3, see the PostGIS documentation PostGIS Functions new or enhanced in 3.3 and Release 3.3.2.

This table lists the PostGIS extensions support by WarehousePG PostGIS.

Table 1. WarehousePG PostGIS Extensions

PostGIS Extension	WarehousePG PostGIS Notes
`postgis` PostGIS and PostGIS Raster support	Supported. Both PostGIS and PostGIS Raster are enabled when the WarehousePG `postgis` extension is enabled.
`postgis_tiger_geocoder` The US TIGER geocoder	Supported. Installed with WarehousePG PostGIS. Requires the `postgis` and `fuzzystrmatch` extensions. The US TIGER geocoder converts addresses (like a street address) to geographic coordinates.
`address_standardizer` Rule-based address standardizer	Supported. Installed but not enabled with WarehousePG PostGIS. Can be used with TIGER geocoder. A single line address parser that takes an input address and normalizes it based on a set of rules stored in a table and helper `lex` and `gaz` tables.
`address_standardizer_data_us` Sample rules tables for US address data	Supported. Installed but not enabled with WarehousePG PostGIS. Can be used with the address standardizer. The extension contains `gaz`, `lex`, and `rules` tables for US address data. If you are using other types of tables, see PostGIS Extension Limitations.
`fuzzystrmatch` Fuzzy string matching	Supported. This extension is bundled but not enabled with WarehousePG Database. Required for the PostGIS TIGER geocoder.

> **Note** The PostGIS topology extension `postgis_topology` and the PostGIS 3D and geoprocessing extension `postgis_sfcgal` are not supported by WarehousePG PostGIS and are not included in the WarehousePG PostGIS extension package.

For information about the PostGIS extensions, see the PostGIS documentation.

For information about WarehousePG PostGIS feature support, see PostGIS Extension Support and Limitations.

Enabling and Removing PostGIS Support

This section describes how to enable and remove PostGIS and the supported PostGIS extensions, and how to configure PostGIS Raster.

Enabling PostGIS Support

To enable PostGIS support, install the WarehousePG PostGIS extension package into the WarehousePG cluster, and then use the `CREATE EXTENSION` command to enable PostGIS support for an individual database.

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Installing the WarehousePG PostGIS Extension Package

After installing the package, source the `greenplum_path.sh` file and restart WarehousePG. This command restarts WarehousePG.

```
gpstop -ra
```

Installing the WarehousePG PostGIS extension package updates the WarehousePG cluster, including installing the supported PostGIS extensions to the system and updating `greenplum_path.sh` file with these lines for PostGIS Raster support.

```
export GDAL_DATA=$GPHOME/share/gdal
export POSTGIS_ENABLE_OUTDB_RASTERS=0
export POSTGIS_GDAL_ENABLED_DRIVERS=DISABLE_ALL
```

Using the CREATE EXTENSION Command

These steps enable the PostGIS extension and the extensions that are used with PostGIS.

1. To enable PostGIS and PostGIS Raster in a database, run this command after logging into the database.

   ```
   CREATE EXTENSION postgis ;
   ```

   To enable PostGIS and PostGIS Raster in a specific schema, create the schema, set the `search_path` to the PostGIS schema, and then enable the `postgis` extension with the `WITH SCHEMA` clause.

   ```
   SHOW search_path ; -- display the current search_path
   CREATE SCHEMA <schema_name> ;
   SET search_path TO <schema_name> ;
   CREATE EXTENSION postgis WITH SCHEMA <schema_name> ;
   ```

   After enabling the extension, reset the `search_path` and include the PostGIS schema in the `search_path` if needed.

2. If needed, enable the PostGIS TIGER geocoder after enabling the `postgis` extension.

   To enable the PostGIS TIGER geocoder, you must enable the `fuzzystrmatch` extension before enabling `postgis_tiger_geocoder`. These two commands enable the extensions.

   ```
   CREATE EXTENSION fuzzystrmatch ;
   CREATE EXTENSION postgis_tiger_geocoder ;
   ```

3. If needed, enable the rules-based address standardizer and add rules tables for the standardizer. These commands enable the extensions.

   ```
   CREATE EXTENSION address_standardizer ;
   CREATE EXTENSION address_standardizer_data_us ;
   ```

Enabling GDAL Raster Drivers

PostGIS uses GDAL raster drivers when processing raster data with commands such as `ST_AsJPEG()`. As the default, PostGIS deactivates all raster drivers. You enable raster drivers by setting the value of the `POSTGIS_GDAL_ENABLED_DRIVERS` environment variable in the `greenplum_path.sh` file on all WarehousePG hosts.

Alternatively, you can do it at the session level by setting `postgis.gdal_enabled_drivers`. For a WarehousePG session, this example `SET` command enables three GDAL raster drivers.

```
SET postgis.gdal_enabled_drivers TO 'GTiff PNG JPEG';
```

This `SET` command sets the enabled drivers to the default for a session.

```
SET postgis.gdal_enabled_drivers = default;
```

To see the list of supported GDAL raster drivers for a WarehousePG cluster, run the `raster2pgsql` utility with the `-G` option on the WarehousePG coordinator.

```
raster2pgsql -G
```

The command lists the driver long format name. The *GDAL Raster* table at https://gdal.org/drivers/raster/index.html lists the long format names and the corresponding codes that you specify as the value of the environment variable. For example, the code for the long name Portable Network Graphics is `PNG`. This example `export` line enables four GDAL raster drivers.

```
export POSTGIS_GDAL_ENABLED_DRIVERS="GTiff PNG JPEG GIF"
```

The `gpstop -r` command restarts the WarehousePG cluster to use the updated settings in the `greenplum_path.sh` file.

After you have updated the `greenplum_path.sh` file on all hosts, and have restarted the WarehousePG cluster, you can display the enabled raster drivers with the `ST_GDALDrivers()` function. This `SELECT` command lists the enabled raster drivers.

```
SELECT short_name, long_name FROM ST_GDALDrivers();
```

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Enabling Out-of-Database Rasters

After installing PostGIS, the default setting `POSTGIS_ENABLE_OUTDB_RASTERS=0` in the `greenplum_path.sh` file deactivates support for out-of-database rasters. To enable this feature, you can set the value to true (a non-zero value) on all hosts and restart the WarehousePG cluster.

You can also activate or deactivate this feature for a WarehousePG session. For example, this `SET` command enables the feature for the current session.

```
SET postgis.enable_outdb_rasters = true;
```

> **Note** When the feature is enabled, the server configuration parameter `postgis.gdal_enabled_drivers` determines the accessible raster formats.

Removing PostGIS Support

You use the `DROP EXTENSION` command to remove support for the PostGIS extension and the extensions that are used with PostGIS.

Removing PostGIS support from a database does not remove these PostGIS Raster environment variables from the `greenplum_path.sh` file: `GDAL_DATA`, `POSTGIS_ENABLE_OUTDB_RASTERS`, `POSTGIS_GDAL_ENABLED_DRIVERS`. The environment variables are removed when you uninstall the PostGIS extension package.

> **Caution** Removing PostGIS support from a database drops PostGIS database objects from the database without warning. Users accessing PostGIS objects might interfere with the dropping of PostGIS objects. SeeNotes.

Using the DROP EXTENSION Command

Depending on the extensions you enabled for PostGIS, drop support for the extensions in the database.

1. If you enabled the address standardizer and sample rules tables, these commands drop support for those extensions from the current database.

   ```
   DROP EXTENSION IF EXISTS address_standardizer_data_us;
   DROP EXTENSION IF EXISTS address_standardizer;
   ```

2. If you enabled the TIGER geocoder and the `fuzzystrmatch` extension to use the TIGER geocoder, these commands drop support for those extensions.

   ```
   DROP EXTENSION IF EXISTS postgis_tiger_geocoder;
   DROP EXTENSION IF EXISTS fuzzystrmatch;
   ```

3. Drop support for PostGIS and PostGIS Raster. This command drops support for those extensions.

   ```
   DROP EXTENSION IF EXISTS postgis;
   ```

   If you enabled support for PostGIS and specified a specific schema with the `CREATE EXTENSION` command, you can update the `search_path` and drop the PostGIS schema if required.

Notes

Removing PostGIS support from a database drops PostGIS objects from the database. Dropping the PostGIS objects cascades to objects that reference the PostGIS objects. Before removing PostGIS support, ensure that no users are accessing the database. Users accessing PostGIS objects might interfere with dropping PostGIS objects.

For example, this `CREATE TABLE` command creates a table with column `b` that is defined with the PostGIS `geometry` data type.

```
CREATE TABLE test(a int, b geometry) DISTRIBUTED RANDOMLY;
```

This is the table definition in a database with PostGIS enabled.

```
\d test
 Table "public.test"
 Column |   Type   | Modifiers
--------+----------+-----------
 a      | integer  |
 b      | geometry |
Distributed randomly
```

This is the table definition in a database after PostGIS support has been removed.

```
\d test
  Table "public.test"
 Column |  Type   | Modifiers
--------+---------+-----------
 a      | integer |
Distributed randomly
```

Usage

The following example SQL statements create non-OpenGIS tables and geometries.

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```
CREATE TABLE geom_test ( gid int4, geom geometry,
  name varchar(25) );

INSERT INTO geom_test ( gid, geom, name )
  VALUES ( 1, 'POLYGON((0 0 0,0 5 0,5 5 0,5 0 0,0 0 0))', '3D Square');
INSERT INTO geom_test ( gid, geom, name )
  VALUES ( 2, 'LINESTRING(1 1 1,5 5 5,7 7 5)', '3D Line' );
INSERT INTO geom_test ( gid, geom, name )
  VALUES ( 3, 'MULTIPOINT(3 4,8 9)', '2D Aggregate Point' );

SELECT * from geom_test WHERE geom &&
  Box3D(ST_GeomFromEWKT('LINESTRING(2 2 0, 3 3 0)'));
```

The following example SQL statements create a table and add a geometry column to the table with a SRID integer value that references an entry in the `SPATIAL_REF_SYS` table. The `INSERT` statements add two geopoints to the table.

```
CREATE TABLE geotest (id INT4, name VARCHAR(32) );
SELECT AddGeometryColumn('geotest','geopoint', 4326,'POINT',2);

INSERT INTO geotest (id, name, geopoint)
  VALUES (1, 'Olympia', ST_GeometryFromText('POINT(-122.90 46.97)', 4326));
INSERT INTO geotest (id, name, geopoint)
  VALUES (2, 'Renton', ST_GeometryFromText('POINT(-122.22 47.50)', 4326));

SELECT name,ST_AsText(geopoint) FROM geotest;
```

Spatial Indexes

PostgreSQL provides support for GiST spatial indexing. The GiST scheme offers indexing even on large objects. It uses a system of lossy indexing in which smaller objects act as proxies for larger ones in the index. In the PostGIS indexing system, all objects use their bounding boxes as proxies in the index.

Building a Spatial Index

You can build a GiST index as follows:

```
CREATE INDEX indexname
  ON tablename
  USING GIST ( geometryfield );
```

PostGIS Extension Support and Limitations

This section describes WarehousePG PostGIS extension feature support and limitations. In general, the WarehousePG PostGIS extension does not support the following features:

- The PostGIS topology extension `postgis_topology`
- The PostGIS 3D and geoprocessing extension `postgis_sfcgal`
- A small number of user defined functions and aggregates
- PostGIS long transactions

For the PostGIS extensions supported by WarehousePG PostGIS, see WarehousePG PostGIS Extension.

Supported PostGIS Data Types

WarehousePG PostGIS extension supports these PostGIS data types:

- box2d
- box3d
- geometry
- geography

For a list of PostGIS data types, operators, and functions, see thePostGIS reference documentation.

Supported PostGIS Raster Data Types

WarehousePG PostGIS supports these PostGIS Raster data types.

- geomval
- addbandarg
- rastbandarg
- raster
- reclassarg
- summarystats
- unionarg

For information about PostGIS Raster data Management, queries, and applications, see thePostGIS documentation.

For a list of PostGIS Raster data types, operators, and functions, see thePostGIS Raster reference documentation.

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Supported PostGIS Index

WarehousePG PostGIS extension supports the GiST (Generalized Search Tree) index.

PostGIS Extension Limitations

This section lists the WarehousePG PostGIS extension limitations for user-defined functions (UDFs), data types, and aggregates.

- Data types and functions related to PostGIS topology functionality, such as TopoGeometry, are not supported by WarehousePG.
- These PostGIS aggregates are not supported by WarehousePG:
    - ST_Collect
    - ST_MakeLine

  On a WarehousePG with multiple segments, the aggregate might return different answers if it is called several times repeatedly.
- WarehousePG does not support PostGIS long transactions.

  PostGIS relies on triggers and the PostGIS table `public.authorization_table` for long transaction support. When PostGIS attempts to acquire locks for long transactions, WarehousePG reports errors citing that the function cannot access the relation, `authorization_table`.
- The `_postgis_index_extent` function is not supported on WarehousePG 7 due to its dependence on spatial index operations.
- The `<->` operator (`geometry <-> geometry`) returns the centroid/centroid distance for WarehousePG 7.
- The TIGER geocoder extension is supported. However, upgrading the TIGER geocoder extension is not supported.
- The `standardize_address()` function uses `lex`, `gaz` or `rules` tables as parameters. If you are using tables apart from `us_lex`, `us_gaz` or `us_rules`, you should create them with the distribution policy `DISTRIBUTED REPLICATED` to work for WarehousePG.

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4.7.4 Geospatial Indexing with H3 and H3-PG

H3 is a geospatial indexing system using a hexagonal grid that can be (approximately) subdivided into finer and finer hexagonal grids. It includes functions for converting from latitude and longitude coordinates to the containing H3 cell, finding the center of H3 cells, finding the boundary geometry of H3 cells, finding neighbors of H3 cells, and more.

H3-PG is a PostgreSQL extension that adds bindings for H3 functions and compatibility with PostGIS defined types.

For information about H3, see https://h3geo.org/

WarehousePG H3-PG Extension

The WarehousePG H3-PG extension package is installed with WarehousePG.

WarehousePG supports the H3 extension with these component versions:

- H3 4.1.3
- PostGIS 3.3.2

For information about the supported WarehousePG extension packages and software versions, see Extensions.

For information about WarehousePG PostGIS feature support, see WarehousePG PostGIS.

Enabling H3 Support

To enable H3 support first enable plpython3u support with the `CREATE LANGUAGE plpython3u` command on your target database. If your database already has this language enabled you can skip this step. Next, use the `CREATE EXTENSION h3_postgis CASCADE` command on your target database. This command will install the following extensions: `postgis`, `postgis_raster`, `h3`, and `h3_postgis`.

Removing H3 Support

You use the `DROP EXTENSION` command to remove support for the H3 extension and the extensions that are used with H3.

> **Caution** Removing H3 support from a database drops H3 database objects from the database without warning. Users accessing H3 objects might interfere with the dropping of H3 objects. Please refer to the following note from PostGIS documentation for a detailed explanation: Notes.

Using the DROP EXTENSION Command

Depending on the extensions you enabled for PostGIS, drop support for the extensions in the database.

1. Use the following commands to drop the H3-PG SQL bindings and H3 library.

```
DROP EXTENSION IF EXISTS h3_postgis;
DROP EXTENSION IF EXISTS h3;
```

2. If you want to drop support for PostGIS and PostGIS raster as well, use the following commands.

```
DROP EXTENSION IF EXISTS postgis_raster;
DROP EXTENSION IF EXISTS postgis;
```

Usage

Create a table with a geometry column. The `INSERT` statements add 10 geopoints to the table.

```
DROP TABLE IF EXISTS test_buildings;
CREATE TABLE test_buildings (gid INTEGER, type VARCHAR(32), center GEOGRAPHY) DISTRIBUTED BY (gid);

INSERT INTO test_buildings (gid, type, center)
VALUES (1, '', 'POINT(-78.88054167312363 43.03597938296738)');
INSERT INTO test_buildings (gid, type, center)
VALUES (2, '', 'POINT(-78.25103469999999 42.987796800000005)');
INSERT INTO test_buildings (gid, type, center)
VALUES (3, '', 'POINT(-77.278319 43.056357)');
INSERT INTO test_buildings (gid, type, center)
VALUES (4, '', 'POINT(-76.53755992503561 42.486039090444734)');
INSERT INTO test_buildings (gid, type, center)
VALUES (5, '', 'POINT(-77.35210400000001 42.745183)');
INSERT INTO test_buildings (gid, type, center)
VALUES (6, '', 'POINT(-76.4586205 42.20662450000001)');
INSERT INTO test_buildings (gid, type, center)
VALUES (7, '', 'POINT(-73.99734793983018 41.99385572155095)');
INSERT INTO test_buildings (gid, type, center)
VALUES (8, 'house', 'POINT(-72.97949770000001 40.83532615000001)');
INSERT INTO test_buildings (gid, type, center)
VALUES (9, 'house', 'POINT(-72.95980417527308 40.8958175447567)');
INSERT INTO test_buildings (gid, type, center)
VALUES (10, 'house', 'POINT(-72.46734516736213 41.046857297778395)');
```

Find H3 indexes at resolution 7 and redistribute the data.

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```
SELECT h3_redistribute_table('test_buildings', 'h3_test_buildings', 'gid', 'center', 7, 'type');
```

Create a different table with existing H3 indexes.

```
DROP TABLE IF EXISTS h3_test_incidents;
CREATE TABLE h3_test_incidents (gid INTEGER, h3_res7 h3index) DISTRIBUTED BY (gid);

INSERT INTO h3_test_incidents (gid, h3_res7)
VALUES (1,'872a1070bffffff');
INSERT INTO h3_test_incidents (gid, h3_res7)
VALUES (2,'872a10764ffffff');
INSERT INTO h3_test_incidents (gid, h3_res7)
VALUES (3,'872a1072dffffff');
INSERT INTO h3_test_incidents (gid, h3_res7)
VALUES (4,'872a10743ffffff');
INSERT INTO h3_test_incidents (gid, h3_res7)
VALUES (5,'872a100d9ffffff');
INSERT INTO h3_test_incidents (gid, h3_res7)
VALUES (6,'872a1070bffffff');
INSERT INTO h3_test_incidents (gid, h3_res7)
VALUES (7,'872a10764ffffff');
INSERT INTO h3_test_incidents (gid, h3_res7)
VALUES (8,'872a10740ffffff');
INSERT INTO h3_test_incidents (gid, h3_res7)
VALUES (9,'872a10741ffffff');
INSERT INTO h3_test_incidents (gid, h3_res7)
VALUES (10,'872a10763ffffff');
```

Find every incident that happened within 50 hexes for each building.

```
DROP TABLE IF EXISTS h3_out_table;
SELECT h3_dwithin_batch('h3_test_buildings', 'h3_test_incidents', 'h3_out_table', 'gid', 'gid', '__h3_res7', 'h3_res7', 50);
SELECT * FROM h3_out_table ORDER BY 1,2;
```

Find the hex distance and approximate real world distance between every building of type 'house' and every incident.

```
DROP TABLE IF EXISTS h3_out_table;
CREATE VIEW h3_test_buildings_view AS SELECT * FROM h3_test_buildings WHERE type = 'house';
SELECT h3_distance_batch('h3_test_buildings_view', 'h3_test_incidents', 'h3_out_table', 'gid', 'gid', '__h3_res7', 'h3_res7');
SELECT * FROM h3_out_table ORDER BY 1,2;
```

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4.7.5 Procedural Languages

WarehousePG supports a pluggable procedural language architecture by virtue of its PostgreSQL heritage. This allows user-defined functions to be written in languages other than SQL and C. It may be more convenient to develop analytics functions in a familiar procedural language compared to using only SQL constructs. For example, suppose you have existing Python code that you want to use on data in WarehousePG, you can wrap this code in a PL/Python function and call it from SQL.

The available WarehousePG procedural languages are typically packaged as extensions. You register a language in a database using the CREATE EXTENSION command. You remove a language from a database with DROP EXTENSION.

The WarehousePG distribution supports the following procedural languages; refer to the linked language documentation for installation and usage instructions:

- PL/Java
- PL/Perl
- PL/pgSQL
- PL/Python
- PL/R

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4.7.5.1 PL/Java Language

This section contains an overview of the WarehousePG PL/Java language.

- About PL/Java
- About WarehousePG PL/Java
- Installing Java
- Installing PL/Java
- Enabling PL/Java and Installing JAR Files
- Uninstalling PL/Java
- Writing PL/Java functions
- Using JDBC
- Exception Handling
- Savepoints
- Logging
- Security
- Some PL/Java Issues and Solutions
- Example
- References

About PL/Java

With the WarehousePG PL/Java extension, you can write Java methods using your favorite Java IDE and install the JAR files that contain those methods into WarehousePG.

WarehousePG PL/Java package is based on the open source PL/Java 1.5.0. WarehousePG PL/Java provides the following features.

- Ability to run PL/Java functions with Java 8, Java 11 and Java 17.
- Ability to specify Java runtime.
- Standardized utilities (modeled after the SQL 2003 proposal) to install and maintain Java code in the database.
- Standardized mappings of parameters and result. Complex types as well as sets are supported.
- An embedded, high performance, JDBC driver utilizing the internal WarehousePG SPI routines.
- Metadata support for the JDBC driver. Both `DatabaseMetaData` and `ResultSetMetaData` are included.
- The ability to return a ResultSet from a query as an alternative to building a ResultSet row by row.
- Full support for savepoints and exception handling.
- The ability to use IN, INOUT, and OUT parameters.
- Two separate WarehousePG languages:
    - pljava, TRUSTED PL/Java language
    - pljavau, UNTRUSTED PL/Java language

- Transaction and Savepoint listeners enabling code execution when a transaction or savepoint is committed or rolled back.
- Integration with GNU GCJ on selected platforms.

A function in SQL will appoint a static method in a Java class. In order for the function to run, the appointed class must available on the class path specified by the WarehousePG server configuration parameter `pljava_classpath`. The PL/Java extension adds a set of functions that helps installing and maintaining the java classes. Classes are stored in normal Java archives, JAR files. A JAR file can optionally contain a deployment descriptor that in turn contains SQL commands to be run when the JAR is deployed or undeployed. The functions are modeled after the standards proposed for SQL 2003.

PL/Java implements a standardized way of passing parameters and return values. Complex types and sets are passed using the standard JDBC ResultSet class.

A JDBC driver is included in PL/Java. This driver calls WarehousePG internal SPI routines. The driver is essential since it is common for functions to make calls back to the database to fetch data. When PL/Java functions fetch data, they must use the same transactional boundaries that are used by the main function that entered PL/Java execution context.

PL/Java is optimized for performance. The Java virtual machine runs within the same process as the backend to minimize call overhead. PL/Java is designed with the objective to enable the power of Java to the database itself so that database intensive business logic can run as close to the actual data as possible.

The standard Java Native Interface (JNI) is used when bridging calls between the backend and the Java VM.

About WarehousePG PL/Java

There are a few key differences between the implementation of PL/Java in standard PostgreSQL and WarehousePG.

Functions

The following functions are not supported in WarehousePG. The classpath is handled differently in a distributed WarehousePG environment than in the PostgreSQL environment.

- `sqlj.install_jar`
- `sqlj.replace_jar`
- `sqlj.remove_jar`
- `sqlj.get_classpath`
- `sqlj.set_classpath`

WarehousePG uses the `pljava_classpath` server configuration parameter in place of the `sqlj.set_classpath` function.

Server Configuration Parameters

The following server configuration parameters are used by PL/Java in WarehousePG. These parameters replace the `pljava.*` parameters that are used in the standard PostgreSQL PL/Java implementation:

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- `pljava_classpath`

  A colon (`:`) separated list of the jar files containing the Java classes used in any PL/Java functions. The jar files must be installed in the same locations on all WarehousePG hosts. With the trusted PL/Java language handler, jar file paths must be relative to the `$GPHOME/lib/postgresql/java/` directory. With the untrusted language handler (javaU language tag), paths may be relative to `$GPHOME/lib/postgresql/java/` or absolute.

  The server configuration parameter `pljava_classpath_insecure` controls whether the server configuration parameter `pljava_classpath` can be set by a user without WarehousePG superuser privileges. When `pljava_classpath_insecure` is enabled, WarehousePG developers who are working on PL/Java functions do not have to be database superusers to change `pljava_classpath` .

  > **Caution** Enabling `pljava_classpath_insecure` exposes a security risk by giving non-administrator database users the ability to run unauthorized Java methods.

- `pljava_statement_cache_size`

  Sets the size in KB of the Most Recently Used (MRU) cache for prepared statements.

- `pljava_release_lingering_savepoints`

  If `TRUE` , lingering savepoints will be released on function exit. If `FALSE` , they will be rolled back.

- `pljava_vmoptions`

  Defines the start up options for the WarehousePG Java VM.

See the *WarehousePG Reference Guide* for information about the WarehousePG server configuration parameters.

Installing Java

PL/Java requires a Java runtime environment on each WarehousePG host. Ensure that the same Java environment is at the same location on all hosts: coordinators and segments. The command `java -version` displays the Java version.

The commands that you use to install Java depend on the host system operating system and Java version. To install OpenJDK 8, OpenJDK 11 or OpenJDK 17 (Java 8 JDK, Java 11 JDK, Java 17 JDK) on RHEL/Oracle/Rocky Linux:

```
$ sudo yum install java-<version>-openjdk-devel
```

For OpenJDK 8 the version is `1.8.0` , for OpenJDK 11 the version is `11` , for OpenJDK 17 the version is `17` .

After installing OpenJDK on a RHEL system, run this `update-alternatives` command to change the default Java. Enter the number that represents the OpenJDK version to use as the default.

```
$ sudo update-alternatives --config java
```

> **Note** When configuring host systems, you can use the gpssh utility to run bash shell commands on multiple remote hosts.

Installing PL/Java

For WarehousePG, the PL/Java extension is available as a package.

To install and use PL/Java:

1. Specify the Java version used by PL/Java. Set the environment variables `JAVA_HOME` and `LD_LIBRARY_PATH` in the `greenplum_path.sh` .
2. Install the WarehousePG PL/Java extension.
3. Enable the language for each database where you intend to use PL/Java.
4. Install user-created JAR files containing Java methods into the same directory on all WarehousePG hosts.
5. Add the name of the JAR file to the WarehousePG server configuration parameter `pljava_classpath` . The parameter lists the installed JAR files. For information about the parameter, see the *WarehousePG Reference Guide*.

Installing the WarehousePG PL/Java Extension

Before you install the PL/Java extension, make sure that your WarehousePG is running, you have sourced `greenplum_path.sh` , and that the `$COORDINATOR_DATA_DIRECTORY` and `$GPHOME` variables are set.

1. Download the PL/Java extension package then copy it to the coordinator host.

2. Install the software extension package

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3. Ensure that the environment variables `JAVA_HOME` and `LD_LIBRARY_PATH` are set properly in `$GPHOME/greenplum_path.sh` on all WarehousePG hosts.

    - Set the `JAVA_HOME` variable to the directory where your Java Runtime is installed. For example, for Oracle JRE this directory would be `/usr/java/latest`. For OpenJDK, the directory is `/usr/lib/jvm`. This example changes the environment variable to use `/usr/lib/jvm`.

      ```
      export JAVA_HOME=/usr/lib/jvm
      ```

    - Set the `LD_LIBRARY_PATH` to include the directory with the Java server runtime libraries. PL/Java depends on `libjvm.so` and the shared object should be in your `LD_LIBRARY_PATH`. By default, `libjvm.so` is available in `$JAVA_HOME/lib/server` with JDK 11 and JDK 17, or in `$JAVA_HOME/jre/lib/amd64/server` with JDK 8. This example adds the JDK 11 directory to the environment variable.

      ```
      export LD_LIBRARY_PATH=$GPHOME/lib:$GPHOME/ext/python/lib:$JAVA_HOME/lib/server:$LD_LIBRARY_PATH
      ```

    This example gpsync command copies the file to all hosts specified in the file `gphosts_file`.

    ```
    $ gpsync -f gphosts_file $GPHOME/greenplum_path.sh
    =:$GPHOME/greenplum_path.sh
    ```

4. Reload `greenplum_path.sh`.

    ```
    $ source $GPHOME/greenplum_path.sh
    ```

5. Restart WarehousePG.

    ```
    $ gpstop -r
    ```

Enabling PL/Java and Installing JAR Files

Perform the following steps as the WarehousePG administrator `gpadmin`.

1. Enable PL/Java in a database by running the `CREATE EXTENSION` command to register the language. For example, this command enables PL/Java in the `testdb` database:

    ```
    $ psql -d testdb -c 'CREATE EXTENSION pljava;'
    ```

    > **Note** The PL/Java `install.sql` script, used in previous releases to register the language, is deprecated.

2. Copy your Java archives (JAR files) to the same directory on all WarehousePG hosts. This example uses the WarehousePG `gpsync` utility to copy the file `myclasses.jar` to the directory `$GPHOME/lib/postgresql/java/`:

    ```
    $ gpsync -f gphosts_file myclasses.jar
    =:/usr/edb/whpg7/lib/postgresql/java/
    ```

    The file `gphosts_file` contains a list of the WarehousePG hosts.

3. Set the `pljava_classpath` server configuration parameter in the coordinator `postgresql.conf` file. For this example, the parameter value is a colon (:) separated list of the JAR files. For example:

    ```
    $ gpconfig -c pljava_classpath -v 'examples.jar:myclasses.jar'
    ```

    The file `examples.jar` is installed when you install the PL/Java extension package

    > **Note** If you install JAR files in a directory other than `$GPHOME/lib/postgresql/java/`, you must specify the absolute path to the JAR file. Each JAR file must be in the same location on all WarehousePG hosts. For more information about specifying the location of JAR files, see the information about the `pljava_classpath` server configuration parameter in the *WarehousePG Reference Guide*.

4. Reload the `postgresql.conf` file.

    ```
    $ gpstop -u
    ```

5. (optional) WarehousePG provides an `examples.sql` file containing sample PL/Java functions that you can use for testing. Run the commands in this file to create the test functions (which use the Java classes in `examples.jar`).

    ```
    $ psql -f $GPHOME/share/postgresql/pljava/examples.sql
    ```

Uninstalling PL/Java

- Remove PL/Java Support for a Database

Remove PL/Java Support for a Database

Use the `DROP EXTENSION` command to remove support for PL/Java from a database. For example, this command deactivates the PL/Java language in the `testdb` database:

```
$ psql -d testdb -c 'DROP EXTENSION pljava;'
```

The default command fails if any existing objects (such as functions) depend on the language. Specify the `CASCADE` option to also drop all dependent objects, including functions that you created with PL/Java.

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> **Note** The PL/Java `uninstall.sql` script, used in previous releases to remove the language registration, is deprecated.

Writing PL/Java functions

Information about writing functions with PL/Java.

- SQL Declaration
- Type Mapping
- NULL Handling
- Complex Types
- Returning Complex Types
- Returning Complex Types
- Functions That Return Sets
- Returning a SETOF <scalar type>
- Returning a SETOF <complex type>

SQL Declaration

A Java function is declared with the name of a class and a static method on that class. The class will be resolved using the classpath that has been defined for the schema where the function is declared. If no classpath has been defined for that schema, the public schema is used. If no classpath is found there either, the class is resolved using the system classloader.

The following function can be declared to access the static method `getProperty` on `java.lang.System` class:

```
CREATE FUNCTION getsysprop(VARCHAR)
  RETURNS VARCHAR
  AS 'java.lang.System.getProperty'
  LANGUAGE java;
```

Run the following command to return the Java `user.home` property:

```
SELECT getsysprop('user.home');
```

Type Mapping

Scalar types are mapped in a straight forward way. This table lists the current mappings.

PostgreSQL	Java
bool	boolean
char	byte
int2	short
int4	int
int8	long
varchar	java.lang.String
text	java.lang.String
bytea	byte[ ]
date	java.sql.Date
time	java.sql.Time (stored value treated as local time)
timetz	java.sql.Time
timestamp	java.sql.Timestamp (stored value treated as local time)
timestamptz	java.sql.Timestamp
complex	java.sql.ResultSet
setof complex	java.sql.ResultSet

All other types are mapped to java.lang.String and will utilize the standard `textin` / `textout` routines registered for respective type.

NULL Handling

The scalar types that map to Java primitives can not be passed as `NULL` values. To pass `NULL` values, those types can have an alternative mapping. You enable this mapping by explicitly denoting it in the method reference.

```
CREATE FUNCTION trueIfEvenOrNull(integer)
  RETURNS bool
  AS 'foo.fee.Fum.trueIfEvenOrNull(java.lang.Integer)'
  LANGUAGE java;
```

The Java code would be similar to this:

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```
package foo.fee;
public class Fum
{
  static boolean trueIfEvenOrNull(Integer value)
  {
    return (value == null)
      ? true
      : (value.intValue() % 2) == 0;
  }
}
```

The following two statements both yield true:

```
SELECT trueIfEvenOrNull(NULL);
SELECT trueIfEvenOrNull(4);
```

In order to return `NULL` values from a Java method, you use the object type that corresponds to the primitive (for example, you return `java.lang.Integer` instead of `int`). The PL/Java resolve mechanism finds the method regardless. Since Java cannot have different return types for methods with the same name, this does not introduce any ambiguity.

Complex Types

A complex type will always be passed as a read-only `java.sql.ResultSet` with exactly one row. The ResultSet is positioned on its row so a call to `next()` should not be made. The values of the complex type are retrieved using the standard getter methods of the ResultSet.

Example:

```
CREATE TYPE complexTest
  AS(base integer, incbase integer, ctime timestamptz);
CREATE FUNCTION useComplexTest(complexTest)
  RETURNS VARCHAR
  AS 'foo.fee.Fum.useComplexTest'
  IMMUTABLE LANGUAGE java;
```

In the Java class `Fum`, we add the following static method:

```
public static String useComplexTest(ResultSet complexTest)
throws SQLException
{
  int base = complexTest.getInt(1);
  int incbase = complexTest.getInt(2);
  Timestamp ctime = complexTest.getTimestamp(3);
  return "Base = \"" + base +
    "\", incbase = \"" + incbase +
    "\", ctime = \"" + ctime + "\"";
}
```

Returning Complex Types

Java does not stipulate any way to create a ResultSet. Hence, returning a ResultSet is not an option. The SQL-2003 draft suggests that a complex return value should be handled as an IN/OUT parameter. PL/Java implements a ResultSet that way. If you declare a function that returns a complex type, you will need to use a Java method with boolean return type with a last parameter of type `java.sql.ResultSet`. The parameter will be initialized to an empty updateable ResultSet that contains exactly one row.

Assume that the `complexTest` type in previous section has been created.

```
CREATE FUNCTION createComplexTest(int, int)
  RETURNS complexTest
  AS 'foo.fee.Fum.createComplexTest'
  IMMUTABLE LANGUAGE java;
```

The PL/Java method resolve will now find the following method in the `Fum` class:

```
public static boolean complexReturn(int base, int increment,
  ResultSet receiver)
throws SQLException
{
  receiver.updateInt(1, base);
  receiver.updateInt(2, base + increment);
  receiver.updateTimestamp(3, new
    Timestamp(System.currentTimeMillis()));
  return true;
}
```

The return value denotes if the receiver should be considered as a valid tuple (true) or NULL (false).

Functions That Return Sets

When returning result sets, you should not build a result set before returning it, because building a large result set would consume a large amount of resources. It is better to produce one row at a time. Incidentally, that is what the WarehousePG backend expects a function with SETOF return to do. You can return a SETOF a scalar type such as an `int`, `float` or `varchar`, or you can return a SETOF a complex type.

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Returning a SETOF <scalar type>

In order to return a set of a scalar type, you need create a Java method that returns something that implements the `java.util.Iterator` interface. Here is an example of a method that returns a SETOF `varchar`:

```
CREATE FUNCTION javatest.getSystemProperties()
  RETURNS SETOF varchar
  AS 'foo.fee.Bar.getNames'
  IMMUTABLE LANGUAGE java;
```

This simple Java method returns an iterator:

```
package foo.fee;
import java.util.Iterator;

public class Bar
{
    public static Iterator getNames()
    {
        ArrayList names = new ArrayList();
        names.add("Lisa");
        names.add("Bob");
        names.add("Bill");
        names.add("Sally");
        return names.iterator();
    }
}
```

Returning a SETOF <complex type>

A method returning a SETOF <complex type> must use either the interface `org.postgresql.pljava.ResultSetProvider` or `org.postgresql.pljava.ResultSetHandle`. The reason for having two interfaces is that they cater for optimal handling of two distinct use cases. The former is for cases when you want to dynamically create each row that is to be returned from the SETOF function. The latter makes sense in cases where you want to return the result of a query after it runs.

Using the ResultSetProvider Interface

This interface has two methods. The boolean `assignRowValues(java.sql.ResultSet tupleBuilder, int rowNumber)` and the `void close()` method. The WarehousePG query evaluator will call the `assignRowValues` repeatedly until it returns false or until the evaluator decides that it does not need any more rows. Then it calls close.

You can use this interface the following way:

```
CREATE FUNCTION javatest.listComplexTests(int, int)
  RETURNS SETOF complexTest
  AS 'foo.fee.Fum.listComplexTest'
  IMMUTABLE LANGUAGE java;
```

The function maps to a static java method that returns an instance that implements the `ResultSetProvider` interface.

```
public class Fum implements ResultSetProvider
{
  private final int m_base;
  private final int m_increment;
  public Fum(int base, int increment)
  {
    m_base = base;
    m_increment = increment;
  }
  public boolean assignRowValues(ResultSet receiver, int
currentRow)
  throws SQLException
  {
    // Stop when we reach 12 rows.
    //
    if(currentRow >= 12)
      return false;
    receiver.updateInt(1, m_base);
    receiver.updateInt(2, m_base + m_increment * currentRow);
    receiver.updateTimestamp(3, new
Timestamp(System.currentTimeMillis()));
    return true;
  }
  public void close()
  {
   // Nothing needed in this example
  }
  public static ResultSetProvider listComplexTests(int base,
int increment)
  throws SQLException
  {
    return new Fum(base, increment);
  }
}
```

The `listComplextTests` method is called once. It may return `NULL` if no results are available or an instance of the `ResultSetProvider`. Here the Java class `Fum` implements this interface so it returns an instance of itself. The method `assignRowValues` will then be called repeatedly until it returns false. At that time, close will be called.

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Using the ResultSetHandle Interface

This interface is similar to the `ResultSetProvider` interface in that it has a `close()` method that will be called at the end. But instead of having the evaluator call a method that builds one row at a time, this method has a method that returns a ResultSet. The query evaluator will iterate over this set and deliver the RestulSet contents, one tuple at a time, to the caller until a call to `next()` returns false or the evaluator decides that no more rows are needed.

Here is an example that runs a query using a statement that it obtained using the default connection. The SQL suitable for the deployment descriptor looks like this:

```
CREATE FUNCTION javatest.listSupers()
  RETURNS SETOF pg_user
  AS 'org.postgresql.pljava.example.Users.listSupers'
  LANGUAGE java;
CREATE FUNCTION javatest.listNonSupers()
  RETURNS SETOF pg_user
  AS 'org.postgresql.pljava.example.Users.listNonSupers'
  LANGUAGE java;
```

And in the Java package `org.postgresql.pljava.example` a class `Users` is added:

```
public class Users implements ResultSetHandle
{
  private final String m_filter;
  private Statement m_statement;
  public Users(String filter)
  {
    m_filter = filter;
  }
  public ResultSet getResultSet()
  throws SQLException
  {
    m_statement =
      DriverManager.getConnection("jdbc:default:connection").cr
eateStatement();
    return m_statement.executeQuery("SELECT * FROM pg_user
       WHERE " + m_filter);
  }

  public void close()
  throws SQLException
  {
    m_statement.close();
  }

  public static ResultSetHandle listSupers()
  {
    return new Users("usesuper = true");
  }

  public static ResultSetHandle listNonSupers()
  {
    return new Users("usesuper = false");
  }
}
```

Using JDBC

PL/Java contains a JDBC driver that maps to the PostgreSQL SPI functions. A connection that maps to the current transaction can be obtained using the following statement:

```
Connection conn =
  DriverManager.getConnection("jdbc:default:connection");
```

After obtaining a connection, you can prepare and run statements similar to other JDBC connections. These are limitations for the PL/Java JDBC driver:

- The transaction cannot be managed in any way. Thus, you cannot use methods on the connection such as:
  - `commit()`
  - `rollback()`
  - `setAutoCommit()`
  - `setTransactionIsolation()`
- Savepoints are available with some restrictions. A savepoint cannot outlive the function in which it was set and it must be rolled back or released by that same function.
- A ResultSet returned from `executeQuery()` are always `FETCH_FORWARD` and `CONCUR_READ_ONLY`.
- Metadata is only available in PL/Java 1.1 or higher.
- `CallableStatement` (for stored procedures) is not implemented.
- The types `Clob` or `Blob` are not completely implemented, they need more work. The types `byte[]` and `String` can be used for `bytea` and `text` respectively.

Exception Handling

You can catch and handle an exception in the WarehousePG backend just like any other exception. The backend ErrorData structure is exposed as a property in a class called `org.postgresql.pljava.ServerException` (derived from `java.sql.SQLException`) and the Java try/catch mechanism is synchronized with the backend mechanism.

> **Important** You will not be able to continue running backend functions until your function has returned and the error has been propagated when the backend has generated an exception unless you have used a savepoint. When a savepoint is rolled back, the exceptional condition is reset and you can continue your execution.

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Savepoints

WarehousePG savepoints are exposed using the java.sql.Connection interface. Two restrictions apply.

- A savepoint must be rolled back or released in the function where it was set.
- A savepoint must not outlive the function where it was set.

Logging

PL/Java uses the standard Java Logger. Hence, you can write things like:

```
Logger.getAnonymousLogger().info( "Time is " + new
Date(System.currentTimeMillis()));
```

At present, the logger uses a handler that maps the current state of the WarehousePG configuration setting `log_min_messages` to a valid Logger level and that outputs all messages using the WarehousePG backend function `elog()`.

> **Note** The `log_min_messages` setting is read from the database the first time a PL/Java function in a session is run. On the Java side, the setting does not change after the first PL/Java function execution in a specific session until the WarehousePG session that is working with PL/Java is restarted.

The following mapping apply between the Logger levels and the WarehousePG backend levels.

java.util.logging.Level	WarehousePG Level
SEVERE ERROR	ERROR
WARNING	WARNING
CONFIG	LOG
INFO	INFO
FINE	DEBUG1
FINER	DEBUG2
FINEST	DEBUG3

Security

- Installation
- Trusted Language

Installation

Only a database superuser can install PL/Java. The PL/Java utility functions are installed using SECURITY DEFINER so that they run with the access permissions that were granted to the creator of the functions.

Trusted Language

PL/Java is a *trusted* language. The trusted PL/Java language has no access to the file system as stipulated by PostgreSQL definition of a trusted language. Any database user can create and access functions in a trusted language.

PL/Java also installs a language handler for the language `javau`. This version is *not trusted* and only a superuser can create new functions that use it. Any user can call the functions.

To install both the trusted and untrusted languages, register the extension by running the `'CREATE EXTENSION pljava'` command when Enabling PL/Java and Installing JAR Files.

To install only the trusted language, register the extension by running the `'CREATE EXTENSION pljavat'` command when Enabling PL/Java and Installing JAR Files.

Some PL/Java Issues and Solutions

When writing the PL/Java, mapping the JVM into the same process-space as the WarehousePG backend code, some concerns have been raised regarding multiple threads, exception handling, and memory management. Here are brief descriptions explaining how these issues where resolved.

- Multi-threading
- Exception Handling
- Java Garbage Collector Versus palloc() and Stack Allocation

Multi-threading

Java is inherently multi-threaded. The WarehousePG backend is not. There is nothing stopping a developer from utilizing multiple Threads class in the Java code. Finalizers that call out to the backend might have been spawned from a background Garbage Collection thread. Several third party Java-packages that are likely to be used make use of multiple threads. How can this model coexist with the WarehousePG backend in the same process?

Solution

The solution is simple. PL/Java defines a special object called the `Backend.THREADLOCK`. When PL/Java is initialized, the backend immediately grabs this objects monitor (i.e. it will synchronize on this object). When the backend calls a Java function, the monitor is released and then immediately regained when the call returns. All calls from Java out to backend code are synchronized on the same lock. This ensures that only one thread at a time can call the backend from Java, and only at a time when the backend is awaiting the return of a Java function call.

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Exception Handling

Java makes frequent use of try/catch/finally blocks. WarehousePG sometimes use an exception mechanism that calls `longjmp` to transfer control to a known state. Such a jump would normally effectively bypass the JVM.

Solution

The backend now allows errors to be caught using the macros `PG_TRY/PG_CATCH` / `PG_END_TRY` and in the catch block, the error can be examined using the ErrorData structure. PL/Java implements a `java.sql.SQLException` subclass called `org.postgresql.pljava.ServerException`. The ErrorData can be retrieved and examined from that exception. A catch handler is allowed to issue a rollback to a savepoint. After a successful rollback, execution can continue.

Java Garbage Collector Versus palloc() and Stack Allocation

Primitive types are always be passed by value. This includes the `String` type (this is a must since Java uses double byte characters). Complex types are often wrapped in Java objects and passed by reference. For example, a Java object can contain a pointer to a palloc'ed or stack allocated memory and use native JNI calls to extract and manipulate data. Such data will become stale once a call has ended. Further attempts to access such data will at best give very unpredictable results but more likely cause a memory fault and a crash.

Solution

The PL/Java contains code that ensures that stale pointers are cleared when the MemoryContext or stack where they were allocated goes out of scope. The Java wrapper objects might live on but any attempt to use them will result in a stale native handle exception.

Example

The following simple Java example creates a JAR file that contains a single method and runs the method.

> **Note** The example requires Java SDK to compile the Java file.

The following method returns a substring.

```
{
public static String substring(String text, int beginIndex,
  int endIndex)
    {
    return text.substring(beginIndex, endIndex);
    }
}
```

Enter the java code in a text file `example.class`.

Contents of the file `manifest.txt`:

```
Manifest-Version: 1.0
Main-Class: Example
Specification-Title: "Example"
Specification-Version: "1.0"
Created-By: 1.6.0_35-b10-428-11M3811
Build-Date: 01/20/2013 10:09 AM
```

Compile the java code:

```
javac *.java
```

Create a JAR archive named analytics.jar that contains the class file and the manifest file MANIFEST file in the JAR.

```
jar cfm analytics.jar manifest.txt *.class
```

Upload the jar file to the WarehousePG coordinator host.

Run the `gpsync` utility to copy the jar file to the WarehousePG Java directory. Use the `-f` option to specify the file that contains a list of the coordinator and segment hosts.

```
gpsync -f gphosts_file analytics.jar
=:/usr/edb/whpg7/lib/postgresql/java/
```

Use the `gpconfig` utility to set the WarehousePG `pljava_classpath` server configuration parameter. The parameter lists the installed jar files.

```
gpconfig -c pljava_classpath -v 'analytics.jar'
```

Run the `gpstop` utility with the `-u` option to reload the configuration files.

```
gpstop -u
```

From the `psql` command line, run the following command to show the installed jar files.

```
show pljava_classpath
```

The following SQL commands create a table and define a Java function to test the method in the jar file:

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```
create table temp (a varchar) distributed randomly;
insert into temp values ('my string');
--Example function
create or replace function java_substring(varchar, int, int)
returns varchar as 'Example.substring' language java;
--Example execution
select java_substring(a, 1, 5) from temp;
```

You can place the contents in a file, `mysample.sql` and run the command from a `psql` command line:

```
> \i mysample.sql
```

The output is similar to this:

```
java_substring
----------------
 y st
(1 row)
```

References

The PL/Java Github wiki page - https://github.com/tada/pljava/wiki.

PL/Java 1.5.0 release - https://github.com/tada/pljava/tree/REL1_5_STABLE.

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4.7.5.2 PL/Perl Language

This chapter includes the following information:

- About WarehousePG PL/Perl
- WarehousePG PL/Perl Limitations
- Trusted/Untrusted Language
- Developing Functions with PL/Perl
- About Developing PL/Perl Procedures

About WarehousePG PL/Perl

With the WarehousePG PL/Perl extension, you can write user-defined functions and procedures in Perl that take advantage of its advanced string manipulation operators and functions. PL/Perl provides both trusted and untrusted variants of the language.

PL/Perl is embedded in your WarehousePG distribution. WarehousePG PL/Perl requires Perl to be installed on the system of each database host.

Refer to the PostgreSQL PL/Perl documentation for additional information.

WarehousePG PL/Perl Limitations

Limitations of the WarehousePG PL/Perl language include:

- WarehousePG does not support PL/Perl triggers.
- PL/Perl functions cannot call each other directly.
- SPI is not yet fully implemented.
- If you fetch very large data sets using `spi_exec_query()`, you should be aware that these will all go into memory. You can avoid this problem by using `spi_query()/spi_fetchrow()`. A similar problem occurs if a set-returning function passes a large set of rows back to WarehousePG via a `return` statement. Use `return_next` for each row returned to avoid this problem.
- When a session ends normally, not due to a fatal error, PL/Perl runs any `END` blocks that you have defined. No other actions are currently performed. (File handles are not automatically flushed and objects are not automatically destroyed.)

Trusted/Untrusted Language

PL/Perl includes trusted and untrusted language variants.

The PL/Perl trusted language is named `plperl`. The trusted PL/Perl language restricts file system operations, as well as `require`, `use`, and other statements that could potentially interact with the operating system or database server process. With these restrictions in place, any WarehousePG user can create and run functions in the trusted `plperl` language.

The PL/Perl untrusted language is named `plperlu`. You cannot restrict the operation of functions you create with the `plperlu` untrusted language. Only database superusers have privileges to create untrusted PL/Perl user-defined functions. And only database superusers and other database users that are explicitly granted the permissions can run untrusted PL/Perl user-defined functions.

PL/Perl has limitations with respect to communication between interpreters and the number of interpreters running in a single process. Refer to the PostgreSQL Trusted and Untrusted PL/Perl documentation for additional information.

Enabling and Removing PL/Perl Support

You must register the PL/Perl language with a database before you can create and run a PL/Perl user-defined function within that database. To remove PL/Perl support, you must explicitly remove the extension from each database in which it was registered. You must be a database superuser or owner to register or remove trusted languages in WarehousePGs.

> **Note** Only database superusers may register or remove support for the *untrusted* PL/Perl language `plperlu`.

Before you enable or remove PL/Perl support in a database, ensure that:

- Your WarehousePG is running.
- You have sourced `greenplum_path.sh`.
- You have set the `$COORDINATOR_DATA_DIRECTORY` and `$GPHOME` environment variables.

Enabling PL/Perl Support

For each database in which you want to enable PL/Perl, register the language using the SQLCREATE EXTENSION command. For example, run the following command as the `gpadmin` user to register the trusted PL/Perl language for the database named `testdb`:

```
$ psql -d testdb -c 'CREATE EXTENSION plperl;'
```

Removing PL/Perl Support

To remove support for PL/Perl from a database, run the SQL DROP EXTENSION command. For example, run the following command as the `gpadmin` user to remove support for the trusted PL/Perl language from the database named `testdb`:

```
$ psql -d testdb -c 'DROP EXTENSION plperl;'
```

The default command fails if any existing objects (such as functions) depend on the language. Specify the `CASCADE` option to also drop all dependent objects, including functions that you created with PL/Perl.

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Developing Functions with PL/Perl

You define a PL/Perl function using the standard SQL CREATE FUNCTION syntax. The body of a PL/Perl user-defined function is ordinary Perl code. The PL/Perl interpreter wraps this code inside a Perl subroutine.

You can also create an anonymous code block with PL/Perl. An anonymous code block, called with the SQL DO command, receives no arguments, and whatever value it might return is discarded. Otherwise, a PL/Perl anonymous code block behaves just like a function. Only database superusers create an anonymous code block with the untrusted `plperlu` language.

The syntax of the `CREATE FUNCTION` command requires that you write the PL/Perl function body as a string constant. While it is more convenient to use dollar-quoting, you can choose to use escape string syntax `E''`) provided that you double any single quote marks and backslashes used in the body of the function.

PL/Perl arguments and results are handled as they are in Perl. Arguments you pass in to a PL/Perl function are accessed via the `@_` array. You return a result value with the `return` statement, or as the last expression evaluated in the function. A PL/Perl function cannot directly return a non-scalar type because you call it in a scalar context. You can return non-scalar types such as arrays, records, and sets in a PL/Perl function by returning a reference.

PL/Perl treats null argument values as "undefined". Adding the `STRICT` keyword to the `LANGUAGE` subclause instructs WarehousePG to immediately return null when any of the input arguments are null. When created as `STRICT`, the function itself need not perform null checks.

The following PL/Perl function utilizes the `STRICT` keyword to return the greater of two integers, or null if any of the inputs are null:

```
CREATE FUNCTION perl_max (integer, integer) RETURNS integer AS $$
    if ($_[0] > $_[1]) { return $_[0]; }
    return $_[1];
$$ LANGUAGE plperl STRICT;

SELECT perl_max( 1, 3 );
 perl_max
----------
        3
(1 row)

SELECT perl_max( 1, null );
 perl_max
----------

(1 row)
```

PL/Perl considers anything in a function argument that is not a reference to be a string, the standard WarehousePG external text representation. The argument values supplied to a PL/Perl function are simply the input arguments converted to text form (just as if they had been displayed by a `SELECT` statement). In cases where the function argument is not an ordinary numeric or text type, you must convert the WarehousePG type to a form that is more usable by Perl. Conversely, the `return` and `return_next` statements accept any string that is an acceptable input format for the function's declared return type.

Refer to the PostgreSQL PL/Perl Functions and Arguments documentation for additional information, including composite type and result set manipulation.

Built-in PL/Perl Functions

PL/Perl includes built-in functions to access the database, including those to prepare and perform queries and manipulate query results. The language also includes utility functions for error logging and string manipulation.

The following example creates a simple table with an integer and a text column. It creates a PL/Perl user-defined function that takes an input string argument and invokes the `spi_exec_query()` built-in function to select all columns and rows of the table. The function returns all rows in the query results where the `v` column includes the function input string.

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```
CREATE TABLE test (
    i int,
    v varchar
);
INSERT INTO test (i, v) VALUES (1, 'first line');
INSERT INTO test (i, v) VALUES (2, 'line2');
INSERT INTO test (i, v) VALUES (3, '3rd line');
INSERT INTO test (i, v) VALUES (4, 'different');

CREATE OR REPLACE FUNCTION return_match(varchar) RETURNS SETOF test AS $$
    # store the input argument
    $ss = $_[0];

    # run the query
    my $rv = spi_exec_query('select i, v from test;');

    # retrieve the query status
    my $status = $rv->{status};

    # retrieve the number of rows returned in the query
    my $nrows = $rv->{processed};

    # loop through all rows, comparing column v value with input argument
    foreach my $rn (0 .. $nrows - 1) {
        my $row = $rv->{rows}[$rn];
        my $textstr = $row->{v};
        if( index($textstr, $ss) != -1 ) {
            # match!  return the row.
            return_next($row);
        }
    }
    return undef;
$$ LANGUAGE plperl EXECUTE ON COORDINATOR ;

SELECT return_match( 'iff' );
 return_match
---------------
 (4,different)
(1 row)
```

Refer to the PostgreSQL PL/Perl Built-in Functions documentation for a detailed discussion of available functions.

Global Values in PL/Perl

You can use the global hash map `%_SHARED` to share data, including code references, between PL/Perl function calls for the lifetime of the current session.

The following example uses `%_SHARED` to share data between the user-defined `set_var()` and `get_var()` PL/Perl functions:

```
CREATE OR REPLACE FUNCTION set_var(name text, val text) RETURNS text AS $$
    if ($_SHARED{$_[0]} = $_[1]) {
        return 'ok';
    } else {
        return "cannot set shared variable $_[0] to $_[1]";
    }
$$ LANGUAGE plperl;

CREATE OR REPLACE FUNCTION get_var(name text) RETURNS text AS $$
    return $_SHARED{$_[0]};
$$ LANGUAGE plperl;

SELECT set_var('key1', 'value1');
 set_var
---------
 ok
(1 row)

SELECT get_var('key1');
 get_var
---------
 value1
(1 row)
```

For security reasons, PL/Perl creates a separate Perl interpreter for each role. This prevents accidental or malicious interference by one user with the behavior of another user's PL/Perl functions. Each such interpreter retains its own value of the `%_SHARED` variable and other global state. Two PL/Perl functions share the same value of `%_SHARED` if and only if they are run by the same SQL role.

There are situations where you must take explicit steps to ensure that PL/Perl functions can share data in `%_SHARED`. For example, if an application runs under multiple SQL roles (via `SECURITY DEFINER` functions, use of `SET ROLE`, etc.) in a single session, make sure that functions that need to communicate are owned by the same user, and mark these functions as `SECURITY DEFINER`.

Notes

Additional considerations when developing PL/Perl functions:

- PL/Perl internally utilizes the UTF-8 encoding. It converts any arguments provided in other encodings to UTF-8, and converts return values from UTF-8 back to the original encoding.
- Nesting named PL/Perl subroutines retains the same dangers as in Perl.
- Only the untrusted PL/Perl language variant supports module import. Use `plperlu` with care.

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- Any module that you use in a `plperlu` function must be available from the same location on all WarehousePG hosts.

About Developing PL/Perl Procedures

A PL/Perl procedure is similar to a PL/Perl function. Refer to User-Defined Procedures for more information on procedures in WarehousePG and how they differ from functions.

In a PL/Perl procedure, any return value from the Perl code is ignored.

Output arguments of PL/Perl procedures can be returned as a hash reference:

```
CREATE PROCEDURE perl_triple(INOUT a integer, INOUT b integer) AS
$$
    my ($a, $b) =
@_;
    return {a => $a * 3, b => $b *
3};
$$ LANGUAGE
plperl;

CALL perl_triple(5, 10);
```

`spi_commit()` and `spi_rollback()` can be called only from the top level in a procedure. (Note that it is not possible to run the SQL commands `COMMIT` or `ROLLBACK` via `spi_exec_query()` or similar. Commit and rollback must be done using these functions.) After a transaction is ended, a new transaction is automatically started, so there is no separate function for that.

Here is an example:

```
CREATE PROCEDURE
transaction_test1()
LANGUAGE
plperl
AS $$
foreach my $i (0..9)
{
    spi_exec_query("INSERT INTO tbl1 (a) VALUES
($i)");
    if ($i % 2 == 0)
{
        spi_commit();
    } else
{
        spi_rollback();

}
}
$$;

CALL transaction_test1();
```

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4.7.5.3 PL/Python Language

This section contains an overview of the WarehousePG PL/Python Language.

- About WarehousePG PL/Python
- Enabling and Removing PL/Python support
- Developing Functions with PL/Python
- About Developing PL/Python Procedures
- Installing Python Modules
- Examples
- References

About WarehousePG PL/Python

PL/Python is a loadable procedural language. With the WarehousePG PL/Python extensions, you can write WarehousePG user-defined functions and procedures in Python that take advantage of Python features and modules to quickly build robust database applications.

You can run PL/Python code blocks as anonymous code blocks. See the DO command in the *WarehousePG Reference Guide*.

The WarehousePG PL/Python extension is installed by default with WarehousePG. `plpython3u` supports developing functions using Python 3.11. The WarehousePG installation process installs a Python 3.11 environment to your system as one of its dependencies.

WarehousePG PL/Python Limitations

- WarehousePG does not support PL/Python triggers.
- PL/Python is available only as a WarehousePG untrusted language.
- Updatable cursors (`UPDATE...WHERE CURRENT OF` and `DELETE...WHERE CURRENT OF`) are not supported.

Enabling and Removing PL/Python support

The PL/Python language is installed with WarehousePG. To create and run a PL/Python user-defined function (UDF) in a database, you must register the PL/Python language with the database.

Enabling PL/Python Support

For each database that requires its use, register the PL/Python language with the SQL command `CREATE EXTENSION`. Because PL/Python is an untrusted language, only superusers can register PL/Python with a database.

Run this command as the `gpadmin` user to register PL/Python with Python 3.11 support:

```
$ psql -d testdb -c 'CREATE EXTENSION plpython3u;'
```

PL/Python is registered as an untrusted language.

Removing PL/Python Support

Run this command as the `gpadmin` user to remove support for PL/Python for Python 3.11:

```
$ psql -d testdb -c 'DROP EXTENSION plpython3u;'
```

The default command fails if any existing objects (such as functions) depend on the language. Specify the `CASCADE` option to also drop all dependent objects, including functions that you created with PL/Python.

Developing Functions with PL/Python

The body of a PL/Python user-defined function is a Python script. When the function is called, its arguments are passed as elements of the array `args[]`. Named arguments are also passed as ordinary variables to the Python script. The result is returned from the PL/Python function with `return` statement, or `yield` statement in case of a result-set statement. If you do not provide a return value, Python returns the default `None`. PL/Python translates Python's `None` into the SQL null value.

Data Type Mapping

The WarehousePG to Python data type mapping follows.

WarehousePG Primitive Type	Python Data Type
boolean[1]	bool
bytea	bytes
smallint, bigint, oid	int
real, double	float
numeric	decimal
other primitive types	string
SQL null value	None

[1] When the UDF return type is `boolean`, the WarehousePG evaluates the return value for truth according to Python rules. That is, `0` and empty string are `false`, but notably `'f'` is `true`.

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Example:

```
CREATE OR REPLACE FUNCTION pybool_func(a int) RETURNS boolean AS $$
    if (a > 0):
        return True
    else:
        return False
$$ LANGUAGE plpython3u;

SELECT pybool_func(-1);

 pybool_func
-------------
 f
(1 row)
```

Arrays and Lists

You pass SQL array values into PL/Python functions with a Python list. Similarly, PL/Python functions return SQL array values as a Python list. In the typical PL/Python usage pattern, you will specify an array with `[]`.

The following example creates a PL/Python function that returns an array of integers:

```
CREATE FUNCTION return_py_int_array()
  RETURNS int[]
AS $$
  return [1, 11, 21, 31]
$$ LANGUAGE plpython3u;

SELECT return_py_int_array();
 return_py_int_array
---------------------
 {1,11,21,31}
(1 row)
```

PL/Python treats multi-dimensional arrays as lists of lists. You pass a multi-dimensional array to a PL/Python function using nested Python lists. When a PL/Python function returns a multi-dimensional array, the inner lists at each level must all be of the same size.

The following example creates a PL/Python function that takes a multi-dimensional array of integers as input. The function displays the type of the provided argument, and returns the multi-dimensional array:

```
CREATE FUNCTION return_multidim_py_array(x int4[])
  RETURNS int4[]
AS $$
  plpy.info(x, type(x))
  return x
$$ LANGUAGE plpython3u;

SELECT * FROM return_multidim_py_array(ARRAY[[1,2,3], [4,5,6]]);
INFO:  ([[1, 2, 3], [4, 5, 6]], <class 'list'>)
CONTEXT:  PL/Python function "return_multidim_py_type"
 return_multidim_py_array
--------------------------
 {{1,2,3},{4,5,6}}
(1 row)
```

PL/Python also accepts other Python sequences, such as tuples, as function arguments for backwards compatibility with WarehousePG versions where multi-dimensional arrays were not supported. In such cases, the Python sequences are always treated as one-dimensional arrays because they are ambiguous with composite types.

Composite Types

You pass composite-type arguments to a PL/Python function using Python mappings. The element names of the mapping are the attribute names of the composite types. If an attribute has the null value, its mapping value is `None`.

You can return a composite type result as a sequence type (tuple or list). You must specify a composite type as a tuple, rather than a list, when it is used in a multi-dimensional array. You cannot return an array of composite types as a list because it would be ambiguous to determine whether the list represents a composite type or another array dimension. In the typical usage pattern, you will specify composite type tuples with `()`.

In the following example, you create a composite type and a PL/Python function that returns an array of the composite type:

```
CREATE TYPE type_record AS (
  first text,
  second int4
);

CREATE FUNCTION composite_type_as_list()
  RETURNS type_record[]
AS $$
  return [[('first', 1), ('second', 1)], [('first', 2), ('second', 2)], [('first', 3), ('second', 3)]];
$$ LANGUAGE plpython3u;

SELECT * FROM composite_type_as_list();
                              composite_type_as_list
-------------------------------------------------------------------------------
 {{"(first,1)","(second,1)"},{"(first,2)","(second,2)"},{"(first,3)","(second,3)"}}
(1 row)
```

Refer to the PostgreSQL Arrays, Lists documentation for additional information on PL/Python handling of arrays and composite types.

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Set-Returning Functions

A Python function can return a set of scalar or composite types from any sequence type (for example: tuple, list, set).

In the following example, you create a composite type and a Python function that returns a `SETOF` of the composite type:

```
CREATE TYPE greeting AS (
  how text,
  who text
);

CREATE FUNCTION greet (how text)
  RETURNS SETOF greeting
AS $$
  # return tuple containing lists as composite types
  # all other combinations work also
  return ( {"how": how, "who": "World"}, {"how": how, "who": "WarehousePG"} )
$$ LANGUAGE plpython3u;

select greet('hello');
       greet
-------------------
 (hello,World)
 (hello,WarehousePG)
(2 rows)
```

Running and Preparing SQL Queries

The PL/Python `plpy` module provides two Python functions to run an SQL query and prepare an execution plan for a query, `plpy.execute` and `plpy.prepare`. Preparing the execution plan for a query is useful if you run the query from multiple Python functions.

PL/Python also supports the `plpy.subtransaction()` function to help manage `plpy.execute` calls in an explicit subtransaction. See Explicit Subtransactions in the PostgreSQL documentation for additional information about `plpy.subtransaction()`.

plpy.execute

Calling `plpy.execute` with a query string and an optional limit argument causes the query to be run and the result to be returned in a Python result object. The result object emulates a list or dictionary object. The rows returned in the result object can be accessed by row number and column name. The result set row numbering starts with 0 (zero). The result object can be modified. The result object has these additional methods:

- `nrows` that returns the number of rows returned by the query.
- `status` which is the `SPI_execute()` return value.

For example, this Python statement in a PL/Python user-defined function runs a query.

```
rv = plpy.execute("SELECT * FROM my_table", 5)
```

The `plpy.execute` function returns up to 5 rows from `my_table`. The result set is stored in the `rv` object. If `my_table` has a column `my_column`, it would be accessed as:

```
my_col_data = rv[i]["my_column"]
```

Since the function returns a maximum of 5 rows, the index `i` can be an integer between 0 and 4.

plpy.prepare

The function `plpy.prepare` prepares the execution plan for a query. It is called with a query string and a list of parameter types, if you have parameter references in the query. For example, this statement can be in a PL/Python user-defined function:

```
plan = plpy.prepare("SELECT last_name FROM my_users WHERE
  first_name = $1", [ "text" ])
```

The string `text` is the data type of the variable that is passed for the variable $1. After preparing a statement, you use the function `plpy.execute` to run it:

```
rv = plpy.execute(plan, [ "Fred" ], 5)
```

The third argument is the limit for the number of rows returned and is optional.

When you prepare an execution plan using the PL/Python module the plan is automatically saved. See the Postgres Server Programming Interface (SPI) documentation for information about the execution plans https://www.postgresql.org/docs/12/spi.html.

To make effective use of saved plans across function calls you use one of the Python persistent storage dictionaries `SD` or `GD`.

The global dictionary `SD` is available to store data between function calls. This variable is private static data. The global dictionary `GD` is public data, available to all Python functions within a session. Use GD with care.

Each function gets its own execution environment in the Python interpreter, so that global data and function arguments from `myfunc` are not available to `myfunc2`. The exception is the data in the `GD` dictionary, as mentioned previously.

This example uses the `SD` dictionary:

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```
CREATE FUNCTION usesavedplan() RETURNS trigger AS $$
  if SD.has_key("plan"):
    plan = SD["plan"]
  else:
    plan = plpy.prepare("SELECT 1")
    SD["plan"] = plan

    # rest of function

$$ LANGUAGE plpython3u;
```

Handling Python Errors and Messages

The Python module `plpy` implements these functions to manage errors and messages:

- `plpy.debug`
- `plpy.log`
- `plpy.info`
- `plpy.notice`
- `plpy.warning`
- `plpy.error`
- `plpy.fatal`
- `plpy.debug`

The message functions `plpy.error` and `plpy.fatal` raise a Python exception which, if uncaught, propagates out to the calling query, causing the current transaction or subtransaction to be cancelled. The functions `raise plpy.ERROR(msg)` and `raise plpy.FATAL(msg)` are equivalent to calling `plpy.error` and `plpy.fatal`, respectively. The other message functions only generate messages of different priority levels.

Whether messages of a particular priority are reported to the client, written to the server log, or both is controlled by the WarehousePG server configuration parameters `log_min_messages` and `client_min_messages`. For information about the parameters see the *WarehousePG Reference Guide*.

Using the dictionary GD To Improve PL/Python Performance

In terms of performance, importing a Python module is an expensive operation and can affect performance. If you are importing the same module frequently, you can use Python global variables to load the module on the first invocation and not require importing the module on subsequent calls. The following PL/Python function uses the GD persistent storage dictionary to avoid importing a module if it has already been imported and is in the GD.

```
CREATE FUNCTION pytest() returns text as $$
  if 'mymodule' not in GD:
    import mymodule
    GD['mymodule'] = mymodule
  return GD['mymodule'].sumd([1,2,3])
$$ LANGUAGE plpython3u;
```

About PL/Python Procedures

A PL/Python procedure is similar to a PL/Python function. Refer to User-Defined Procedures for more information on procedures in WarehousePG and how they differ from functions.

In a PL/Python procedure, the result from the Python code must be `None` (typically achieved by ending the procedure without a `return` statement or by using a `return` statement without argument); otherwise, an error will be raised.

You can pass back output parameters of a PL/Python procedure in the same way that you do for a function. For example:

```
CREATE PROCEDURE python_triple(INOUT a integer, INOUT b integer) AS
$$
return (a * 3, b *
3)
$$ LANGUAGE
plpython3u;

CALL python_triple(5,
10);
```

About Transaction Management in Procedures

In a procedure called from the top level or an anonymous code block (`DO` command) called from the top level it is possible to control transactions. To commit the current transaction, call `plpy.commit()`. To roll back the current transaction, call `plpy.rollback()`. (Note that it is not possible to run the SQL commands `COMMIT` or `ROLLBACK` via `plpy.execute()` or similar. You must commit or rollback using these functions.) After a transaction is ended, a new transaction is automatically started, so there is no separate function for that.

Here is an example:

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```
CREATE PROCEDURE
transaction_test1()
LANGUAGE plpython3u
AS $$
for i in range(0,
10):
    plpy.execute("INSERT INTO test1 (a) VALUES (%d)" %
i)
    if i % 2 ==
0:
        plpy.commit()
    else:
        plpy.rollback()
$$;

CALL transaction_test1();
```

A transaction cannot be ended when an explicit subtransaction is active.

Installing Python Modules

When you install a Python module for development with PL/Python, the WarehousePG Python environment must have the module added to it across all segment hosts and mirror hosts in the cluster. When expanding WarehousePG, you must add the Python modules to the new segment hosts.

WarehousePG provides a collection of data science-related Python modules that you can use to easily develop PL/Python functions in WarehousePG. See Python Data Science Module Packages for installation instructions and descriptions of the provided modules.

To develop with modules that are not part of the Python Data Science Module packages, you can use WarehousePG utilities such as `gpssh` and `gpsync` to run commands or copy files to all hosts in the WarehousePG cluster. These sections describe how to use those utilities to install and use additional Python modules:

- Verifying the Python Environment
- Installing Python pip
- Installing Python Packages for Python 3.11
- Building and Installing Python Modules Locally
- Testing Installed Python Modules

Verifying the Python Environment

The plpython3u is built with Python 3.11. To check the Python environment, you can use the `which` command:

```
which python3.11
```

When running shell commands on remote hosts with `gpssh`, specify the `-s` option to source the `greenplum_path.sh` file before running commands on the remote hosts. For example, this command should display the Python installed with WarehousePG on each host specified in the `gpdb_hosts` file.

```
gpssh -s -f gpdb_hosts which python3.11
```

To display the list of currently installed Python modules, run this command.

```
python3.11 -c "help('modules')"
```

You can optionally run `gpssh` in interactive mode to display Python modules on remote hosts. This example starts `gpssh` in interactive mode and lists the Python modules on the WarehousePG host `sdw1`.

```
$ gpssh -s -h sdw1
=> python3.11 -c "help('modules')"
. . .
=> exit
$
```

Installing Python pip

The Python utility `pip` installs Python packages that contain Python modules and other resource files from versioned archive files.

For Python 3.11, use:

```
python3.11 -m ensurepip --default-pip
```

The command runs the `ensurepip` module to bootstrap (install and configure) the `pip` utility from the local Python installation.

You can run this command to ensure the `pip`, `setuptools` and `wheel` projects are current. Current Python projects ensure that you can install Python packages from source distributions or pre-built distributions (wheels).

```
python3.11 -m pip install --upgrade pip setuptools wheel
```

You can use `gpssh` to run the commands on the WarehousePG hosts. This example runs `gpssh` in interactive mode to install `pip` on the hosts listed in the file `gpdb_hosts`.

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```
$ gpssh -s -f gpdb_hosts
=> python3.11 -m ensurepip --default-pip
[centos6-cdw1] Ignoring indexes: https://pypi.python.org/simple
[centos6-cdw1] Collecting setuptools
[centos6-cdw1] Collecting pip
[centos6-cdw1] Installing collected packages: setuptools, pip
[centos6-cdw1] Successfully installed pip-8.1.1 setuptools-20.10.1
[centos6-sdw1] Ignoring indexes: https://pypi.python.org/simple
[centos6-sdw1] Collecting setuptools
[centos6-sdw1] Collecting pip
[centos6-sdw1] Installing collected packages: setuptools, pip
[centos6-sdw1] Successfully installed pip-8.1.1 setuptools-20.10.1
=> exit
$
```

The `=>` is the inactive prompt for `gpssh`. The utility displays the output from each host. The `exit` command exits from `gpssh` interactive mode.

This `gpssh` command runs a single command on all hosts listed in the file `gpdb_hosts`.

```
gpssh -s -f gpdb_hosts python -m pip install --upgrade pip setuptools wheel
```

The utility displays the output from each host.

For more information about installing Python packages, see https://packaging.python.org/tutorials/installing-packages/.

```
python3.11 -m pip install --user numpy scipy
```

The `--user` option attempts to avoid conflicts when installing Python packages.

You can use `gpssh` to run the command on the WarehousePG hosts.

For information about these and other Python packages, see References.

Installing Python Packages to a Non-Standard Location

You can optionally install Python 3.11 modules to a non-standard location by using the `--prefix` option with `pip`. For example:

```
gpssh -s -f gpdb_hosts
=> unset PYTHONHOME
=> unset PYTHONPATH
=> $GPHOME/ext/python3.11 -m pip install --prefix=/home/gpadmin/my_python numpy scipy
```

If you use this option, keep in mind that the `PYTHONPATH` environment variable setting is cleared before initializing or executing functions using `plpython3u`. If you want to use modules installed to a custom location, you must configure the paths to those modules using the WarehousePG configuration parameter `plpython3.python_path` instead of `PYTHONPATH`. For example:

```
$ psql -d testdb
testdb=# SET plpython3.python_path='/home/gpadmin/my_python';
```

WarehousePG uses the value of `plpython3.python_path` to set `PYTHONPATH` in the environment used to create or call `plpython3u` functions.

Ensure that you configure `plpython3.python_path` *before* you create or call `plpython3` functions in a session. If you set or change the parameter after `plpython3u` is initialized you receive the error:

```
ERROR: SET PYTHONPATH failed, the GUC value can only be changed before initializing the python interpreter.
```

To set a default value for the configuration parameter, use `gpconfig` instead:

```
gpconfig -c plpython3.python_path \
    -v "'/home/gpadmin/my_python'" \
    --skipvalidation
gpstop -u
```

Building and Installing Python Modules Locally

If you are building a Python module, you must ensure that the build creates the correct executable. For example on a Linux system, the build should create a 64-bit executable.

Before building a Python module to be installed, ensure that the appropriate software to build the module is installed and properly configured. The build environment is required only on the host where you build the module.

You can use the WarehousePG utilities `gpssh` and `gpsync` to run commands on WarehousePG hosts and to copy files to the hosts.

Testing Installed Python Modules

You can create a simple PL/Python user-defined function (UDF) to validate that Python a module is available in the WarehousePG. This example tests the NumPy module.

This PL/Python UDF imports the NumPy module. The function returns `SUCCESS` if the module is imported, and `FAILURE` if an import error occurs.

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```
CREATE OR REPLACE FUNCTION plpy_test()
returns text
as $$
  try:
      import numpy
      return 'SUCCESS'
  except ImportError:
      return 'FAILURE'
$$ language plpython3u;
```

This `SELECT` command runs the UDF on the all segments by using `gp_dist_random('gp_id')`;

```
SELECT gp_segment_id, plpy_test() from gp_dist_random('gp_id');
```

The `SELECT` command returns `SUCCESS` if the UDF imported the Python module on the WarehousePG segment instance. If the `SELECT` command returns `FAILURE`, you can find the segment host of the segment instance host. The WarehousePG cluster table `gp_segment_configuration` contains information about mirroring and segment configuration. This command returns the host name for a segment ID.

```
SELECT hostname, content AS seg_ID FROM gp_segment_configuration
  WHERE content = <seg_id> ;
```

If `FAILURE` is returned, these are some possible causes:

- A problem accessing required libraries. For the NumPy example, a WarehousePG might have a problem accessing the OpenBLAS libraries or the Python libraries on a segment host.

  Make sure you get no errors when running command on the segment host as the `gpadmin` user. This `gpssh` command tests importing the numpy module on the segment host `cdw1`.

  ```
  gpssh -s -h cdw1 python3.11 -c "import numpy"
  ```

- The `plpython3.python_path` has not been set to the correct location.

Examples

This PL/Python function example uses Python 3.11 and returns the value of pi using the `numpy` module:

```
CREATE OR REPLACE FUNCTION testpi()
  RETURNS float
AS $$
  import numpy
  return numpy.pi
$$ LANGUAGE plpython3u;
```

Use `SELECT` to call the function:

```
SELECT testpi();
       testpi
------------------
 3.14159265358979
(1 row)
```

This PL/Python UDF returns the maximum of two integers:

```
CREATE FUNCTION pymax (a integer, b integer)
RETURNS integer
AS $$
  if (a is None) or (b is None):
    return None
  if a > b:
    return a
  return b
$$ LANGUAGE plpython3u;
```

You can use the `STRICT` property to perform the null handling instead of using the two conditional statements.

```
CREATE FUNCTION pymax (a integer, b integer)
RETURNS integer AS $$
return max(a,b)
$$ LANGUAGE plpython3u STRICT;
```

You can run the user-defined function `pymax` with `SELECT` command. This example runs the UDF and shows the output.

```
SELECT pymax(123, 43);
column1
---------
     123
(1 row)
```

This example that returns data from an SQL query that is run against a table. These two commands create a simple table and add data to the table.

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```
CREATE TABLE sales (id int, year int, qtr int, day int, region text)
  DISTRIBUTED BY (id) ;

INSERT INTO sales VALUES
 (1, 2014, 1,1, 'usa'),
 (2, 2002, 2,2, 'europe'),
 (3, 2014, 3,3, 'asia'),
 (4, 2014, 4,4, 'usa'),
 (5, 2014, 1,5, 'europe'),
 (6, 2014, 2,6, 'asia'),
 (7, 2002, 3,7, 'usa') ;
```

This PL/Python UDF runs a `SELECT` command that returns 5 rows from the table. The Python function returns the `REGION` value from the row specified by the input value. In the Python function, the row numbering starts from 0. Valid input for the function is an integer between 0 and 4.

```
CREATE OR REPLACE FUNCTION mypytest(a integer)
  RETURNS setof text
AS $$
  rv = plpy.execute("SELECT * FROM sales ORDER BY id", 5)
  region =[]
  region.append(rv[a]["region"])
  return region
$$ language plpython3u EXECUTE ON COORDINATOR;
```

Running this `SELECT` statement returns the `REGION` column value from the third row of the result set.

```
SELECT mypytest(2) ;
```

This command deletes the UDF from the database.

```
DROP FUNCTION mypytest(integer) ;
```

This example runs the PL/Python function in the previous example as an anonymous block with the `DO` command. In the example, the anonymous block retrieves the input value from a temporary table.

```
CREATE TEMP TABLE mytemp AS VALUES (2) DISTRIBUTED RANDOMLY;
DO $$
  temprow = plpy.execute("SELECT * FROM mytemp", 1)
  myval = temprow[0]["column1"]
  rv = plpy.execute("SELECT * FROM sales ORDER BY id", 5)
  region = rv[myval]["region"]
  plpy.notice("region is %s" % region)
$$ language plpython3u;
```

References

Technical References

For information about the Python language, see https://www.python.org/.

For information about PL/Python see the PostgreSQL documentation at https://www.postgresql.org/docs/12/plpython.html.

For information about Python Package Index (PyPI), see https://pypi.python.org/pypi.

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4.7.5.4 PL/R Language

This chapter contains the following information:

- About WarehousePG PL/R
- Installing R
- Installing PL/R
- Uninstalling PL/R
- Enabling PL/R Language Support
- Examples
- Downloading and Installing R Packages
- Displaying R Library Information
- Loading R Modules at Startup
- References

About WarehousePG PL/R

PL/R is a procedural language. With the WarehousePG PL/R extension you can write database functions in the R programming language and use R packages that contain R functions and data sets.

For information about supported PL/R versions, see the *WarehousePG Release Notes*.

Installing R

For RHEL/Oracle/Rocky, installing the PL/R package installs R in `$GPHOME/ext/R-<version>` and updates `$GPHOME/greenplum_path.sh` for WarehousePG to use R.

> **Note** You can use the gpssh utility to run bash shell commands on multiple remote hosts.

1. To install R, run these `apt` commands on all host systems.

   ```
   $ sudo apt update && sudo apt install r-base
   ```

   Installing `r-base` also installs dependent packages including `r-base-core`.

2. To configure WarehousePG to use R, add the `R_HOME` environment variable to `$GPHOME/greenplum_path.sh` on all hosts. This example command returns the R home directory.

   ```
   $ R RHOME
   /usr/lib/R
   ```

   Using the previous R home directory as an example, add this line to the file on all hosts.

   ```
   export R_HOME=/usr/lib/R
   ```

3. Source `$GPHOME/greenplum_path.sh` and restart WarehousePG. For example, run these commands on the WarehousePG coordinator host.

   ```
   $ source $GPHOME/greenplum_path.sh
   $ gpstop -r
   ```

Installing PL/R

The PL/R extension is available as a package.

Installing the Extension Package

Before you install the PL/R extension, make sure that your WarehousePG is running, you have sourced `greenplum_path.sh`, and that the `$COORDINATOR_DATA_DIRECTORY` and `$GPHOME` variables are set.

1. Download the PL/R extension package.
2. Copy the PL/R package to the WarehousePG coordinator host.
3. Install the software extension package
4. Source the file `$GPHOME/greenplum_path.sh`.
5. Restart WarehousePG.

   ```
   $ gpstop -r
   ```

Enabling PL/R Language Support

For each database that requires its use, register the PL/R language with the SQL command `CREATE EXTENSION`. Because PL/R is an untrusted language, only superusers can register PL/R with a database. For example, run this command as the `gpadmin` user to register the language with the database named `testdb`:

```
$ psql -d testdb -c 'CREATE EXTENSION plr;'
```

PL/R is registered as an untrusted language.

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Uninstalling PL/R

- Remove PL/R Support for a Database
- Uninstall R (Ubuntu)

When you remove PL/R language support from a database, the PL/R routines that you created in the database will no longer work.

Remove PL/R Support for a Database

For a database that no longer requires the PL/R language, remove support for PL/R with the SQL command `DROP EXTENSION`. Because PL/R is an untrusted language, only superusers can remove support for the PL/R language from a database. For example, run this command as the `gpadmin` user to remove support for PL/R from the database named `testdb`:

```
$ psql -d testdb -c 'DROP EXTENSION plr;'
```

The default command fails if any existing objects (such as functions) depend on the language. Specify the `CASCADE` option to also drop all dependent objects, including functions that you created with PL/R.

Uninstall R (Ubuntu)

For Ubuntu systems, remove R from all WarehousePG host systems. These commands remove R from an Ubuntu system.

```
$ sudo apt remove r-base
$ sudo apt remove r-base-core
```

Removing `r-base` does not uninstall the R executable. Removing `r-base-core` uninstalls the R executable.

Examples

The following are simple PL/R examples.

Example 1: Using PL/R for single row operators

This function generates an array of numbers with a normal distribution using the R function `rnorm()`.

```
CREATE OR REPLACE FUNCTION r_norm(n integer, mean float8,
  std_dev float8) RETURNS float8[ ] AS
$$
  x<-rnorm(n,mean,std_dev)
  return(x)
$$
LANGUAGE 'plr';
```

The following `CREATE TABLE` command uses the `r_norm()` function to populate the table. The `r_norm()` function creates an array of 10 numbers.

```
CREATE TABLE test_norm_var
        AS SELECT id, r_norm(10,0,1) as x
        FROM (SELECT generate_series(1,30:: bigint) AS ID) foo
        DISTRIBUTED BY (id);
```

Example 2: Returning PL/R data.frames in Tabular Form

Assuming your PL/R function returns an R `data.frame` as its output, unless you want to use arrays of arrays, some work is required to see your `data.frame` from PL/R as a simple SQL table:

- Create a `TYPE` in a WarehousePG with the same dimensions as your R `data.frame:`

  ```
  CREATE TYPE t1 AS ...
  ```

- Use this `TYPE` when defining your PL/R function

  ```
  ... RETURNS SET OF t1 AS ...
  ```

Sample SQL for this is given in the next example.

Example 3: Hierarchical Regression using PL/R

The SQL below defines a `TYPE` and runs hierarchical regression using PL/R:

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```
--Create TYPE to store model results
DROP TYPE IF EXISTS wj_model_results CASCADE;
CREATE TYPE wj_model_results AS (
  cs text, coefext float, ci_95_lower float, ci_95_upper float,
  ci_90_lower float, ci_90_upper float, ci_80_lower float,
  ci_80_upper float);

--Create PL/R function to run model in R
DROP FUNCTION IF EXISTS wj_plr_RE(float [ ], text [ ]);
CREATE FUNCTION wj_plr_RE(response float [ ], cs text [ ])
RETURNS SETOF wj_model_results AS
$$
  library(arm)
  y<- log(response)
  cs<- cs
  d_temp<- data.frame(y,cs)
  m0 <- lmer (y ~ 1 + (1 | cs), data=d_temp)
  cs_unique<- sort(unique(cs))
  n_cs_unique<- length(cs_unique)
  temp_m0<- data.frame(matrix0,n_cs_unique, 7))
  for (i in 1:n_cs_unique){temp_m0[i,]<-
    c(exp(coef(m0)$cs[i,1] + c(0,-1.96,1.96,-1.65,1.65,
      -1.28,1.28)*se.ranef(m0)$cs[i]))}
  names(temp_m0)<- c("Coefest", "CI_95_Lower",
    "CI_95_Upper", "CI_90_Lower", "CI_90_Upper",
   "CI_80_Lower", "CI_80_Upper")
  temp_m0_v2<- data.frames(cs_unique, temp_m0)
  return(temp_m0_v2)
$$
LANGUAGE 'plr';

--Run modeling plr function and store model results in a
--table
DROP TABLE IF EXISTS wj_model_results_roi;
CREATE TABLE wj_model_results_roi AS SELECT *
  FROM wj_plr_RE('{1,1,1}', '{"a", "b", "c"}');
```

Downloading and Installing R Packages

R packages are modules that contain R functions and data sets. You can install R packages to extend R and PL/R functionality in WarehousePG.

WarehousePG provides a collection of data science-related R libraries that can be used with the WarehousePG PL/R language. For information about the libraries, seeR Data Science Library Package.

> **Note** If you expand WarehousePG and add segment hosts, you must install the R packages in the R installation of the new hosts.

1. For an R package, identify all dependent R packages and each package web URL. The information can be found by selecting the given package from the following navigation page:

   https://cran.r-project.org/web/packages/available_packages_by_name.html

   As an example, the page for the R package arm indicates that the package requires the following R libraries: Matrix, lattice, lme4, R2WinBUGS, coda, abind, foreign, and MASS.

   You can also try installing the package with `R CMD INSTALL` command to determine the dependent packages.

   For the R installation included with the WarehousePG PL/R extension, the required R packages are installed with the PL/R extension. However, the Matrix package requires a newer version.

2. From the command line, use the `wget` utility to download the `tar.gz` files for the arm package to the WarehousePG coordinator host:

   ```
   wget https://cran.r-project.org/src/contrib/Archive/arm/arm_1.5-03.tar.gz
   ```

   ```
   wget https://cran.r-project.org/src/contrib/Archive/Matrix/Matrix_0.9996875-1.tar.gz
   ```

3. Use the gpsync utility and the `hosts_all` file to copy the `tar.gz` files to the same directory on all nodes of the WarehousePG cluster. The `hosts_all` file contains a list of all the WarehousePG segment hosts. You might require root access to do this.

   ```
   gpsync -f hosts_all Matrix_0.9996875-1.tar.gz =:/home/gpadmin
   ```

   ```
   gpsync -f /hosts_all arm_1.5-03.tar.gz =:/home/gpadmin
   ```

4. Use the `gpssh` utility in interactive mode to log into each WarehousePG segment host (`gpssh -f all_hosts`). Install the packages from the command prompt using the `R CMD INSTALL` command. Note that this may require root access. For example, this R install command installs the packages for the arm package.

   ```
   $R_HOME/bin/R CMD INSTALL Matrix_0.9996875-1.tar.gz   arm_1.5-03.tar.gz
   ```

5. Ensure that the package is installed in the `$R_HOME/library` directory on all the segments (the `gpssh` can be used to install the package). For example, this `gpssh` command list the contents of the R library directory.

   ```
   gpssh -s -f all_hosts "ls $R_HOME/library"
   ```

   The `gpssh` option `-s` sources the `greenplum_path.sh` file before running commands on the remote hosts.

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6. Test if the R package can be loaded.

   This function performs a simple test to determine if an R package can be loaded:

   ```
   CREATE OR REPLACE FUNCTION R_test_require(fname text)
   RETURNS boolean AS
   $BODY$
       return(require(fname,character.only=T))
   $BODY$
   LANGUAGE 'plr';
   ```

   This SQL command checks if the R package arm can be loaded:

   ```
   SELECT R_test_require('arm');
   ```

Displaying R Library Information

You can use the R command line to display information about the installed libraries and functions on the WarehousePG host. You can also add and remove libraries from the R installation. To start the R command line on the host, log into the host as the `gadmin` user and run the script R from the directory `$GPHOME/ext/R-3.3.3/bin`.

This R function lists the available R packages from the R command line:

```
> library()
```

Display the documentation for a particular R package

```
> library(help="<package_name>")
> help(package="<package_name>")
```

Display the help file for an R function:

```
> help("<function_name>")
> ?<function_name>
```

To see what packages are installed, use the R command `installed.packages()`. This will return a matrix with a row for each package that has been installed. Below, we look at the first 5 rows of this matrix.

```
> installed.packages()
```

Any package that does not appear in the installed packages matrix must be installed and loaded before its functions can be used.

An R package can be installed with `install.packages()`:

```
> install.packages("<package_name>")
> install.packages("mypkg", dependencies = TRUE, type="source")
```

Load a package from the R command line.

```
> library(" <package_name> ")
```

An R package can be removed with `remove.packages`

```
> remove.packages("<package_name>")
```

You can use the R command `-e` option to run functions from the command line. For example, this command displays help on the R package MASS.

```
$ R -e 'help("MASS")'
```

Loading R Modules at Startup

PL/R can automatically load saved R code during interpreter initialization. To use this feature, you create the `plr_modules` database table and then insert the R modules you want to auto-load into the table. If the table exists, PL/R will load the code it contains into the interpreter.

In a WarehousePG cluster, table rows are usually distributed so that each row exists at only one segment instance. The R interpreter at each segment instance, however, needs to load all of the modules, so a normally distributed table will not work. You must create the `plr_modules` table as a *replicated table* in the default schema so that all rows in the table are present at every segment instance. For example:

```
CREATE TABLE public.plr_modules {
  modseq int4,
  modsrc text
) DISTRIBUTED REPLICATED;
```

See https://www.joeconway.com/plr/doc/plr-module-funcs.html for more information about using the PL/R auto-load feature.

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References

https://www.r-project.org/ - The R Project home page.

https://cran.r-project.org/web/packages/PivotalR/ - The home page for PivotalR, a package that provides an R interface to operate on WarehousePG tables and views that is similar to the R data.frame. PivotalR also supports using the machine learning package MADlib directly from R.

The following links highlight key topics from the R documentation.

- R Functions and Arguments - https://www.joeconway.com/doc/plr-funcs.html
- Passing Data Values in R - https://www.joeconway.com/doc/plr-data.html
- Aggregate Functions in R - https://www.joeconway.com/doc/plr-aggregate-funcs.html

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4.7.5.5 PL/pgSQL Language

This section contains an overview of the WarehousePG PL/pgSQL language.

- About WarehousePG PL/pgSQL
- PL/pgSQL Plan Caching
- PL/pgSQL Examples
- About Developing PL/pgSQL Procedures
- References

About WarehousePG PL/pgSQL

WarehousePG PL/pgSQL is a loadable procedural language that is installed and registered by default with WarehousePG. You can create user-defined functions and procedures using SQL statements, functions, and operators.

With PL/pgSQL you can group a block of computation and a series of SQL queries inside the database server, thus having the power of a procedural language and the ease of use of SQL. Also, with PL/pgSQL you can use all the data types, operators and functions of WarehousePG SQL.

The PL/pgSQL language is a subset of Oracle PL/SQL. WarehousePG PL/pgSQL is based on Postgres PL/pgSQL. The Postgres PL/pgSQL documentation is at https://www.postgresql.org/docs/12/plpgsql.html

When using PL/pgSQL functions, function attributes affect how WarehousePG creates query plans. You can specify the attribute `IMMUTABLE`, `STABLE`, or `VOLATILE` as part of the `LANGUAGE` clause to classify the type of function. For information about the creating functions and function attributes, see the CREATE FUNCTION command in the *WarehousePG Reference Guide*.

You can run PL/SQL code blocks as anonymous code blocks. See the DO command in the *WarehousePG Reference Guide*.

WarehousePG SQL Limitations

When using WarehousePG PL/pgSQL, limitations include

- Triggers are not supported
- Cursors are forward moving only (not scrollable)
- Updatable cursors (`UPDATE...WHERE CURRENT OF` and `DELETE...WHERE CURRENT OF`) are not supported.
- Parallel retrieve cursors (`DECLARE...PARALLEL RETRIEVE`) are not supported.

For information about WarehousePG SQL conformance, see Summary of WarehousePG Features in the *WarehousePG Reference Guide*.

The PL/pgSQL Language

PL/pgSQL is a block-structured language. The complete text of a function definition must be a block. A block is defined as:

```
[ <label> ]
[ DECLARE
   declarations ]
BEGIN
   statements
END [ <label> ];
```

Each declaration and each statement within a block is terminated by a semicolon (;). A block that appears within another block must have a semicolon after `END`, as shown in the previous block. The `END` that concludes a function body does not require a semicolon.

A label is required only if you want to identify the block for use in an `EXIT` statement, or to qualify the names of variables declared in the block. If you provide a label after `END`, it must match the label at the block's beginning.

> **Important** Do not confuse the use of the `BEGIN` and `END` keywords for grouping statements in PL/pgSQL with the database commands for transaction control. The PL/pgSQL `BEGIN` and `END` keywords are only for grouping; they do not start or end a transaction. Functions are always run within a transaction established by an outer query — they cannot start or commit that transaction, since there would be no context for them to run in. However, a PL/pgSQL block that contains an `EXCEPTION` clause effectively forms a subtransaction that can be rolled back without affecting the outer transaction. For more about the `EXCEPTION` clause, see the PostgreSQL documentation on trapping errors at https://www.postgresql.org/docs/12/plpgsql-control-structures.html#PLPGSQL-ERROR-TRAPPING.

Keywords are case-insensitive. Identifiers are implicitly converted to lowercase unless double-quoted, just as they are in ordinary SQL commands.

Comments work the same way in PL/pgSQL code as in ordinary SQL:

- A double dash (--) starts a comment that extends to the end of the line.
- A /* starts a block comment that extends to the matching occurrence of */.

  Block comments nest.

Any statement in the statement section of a block can be a subblock. Subblocks can be used for logical grouping or to localize variables to a small group of statements.

Variables declared in a subblock mask any similarly-named variables of outer blocks for the duration of the subblock. You can access the outer variables if you qualify their names with their block's label. For example this function declares a variable named `quantity` several times:

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```
CREATE FUNCTION testfunc() RETURNS integer AS $$
<< outerblock >>
DECLARE
   quantity integer := 30;
BEGIN
   RAISE NOTICE 'Quantity here is %', quantity;  -- Prints 30
   quantity := 50;
   --
   -- Create a subblock
   --
   DECLARE
      quantity integer := 80;
   BEGIN
      RAISE NOTICE 'Quantity here is %', quantity;  -- Prints 80
      RAISE NOTICE 'Outer quantity here is %', outerblock.quantity;  -- Prints 50
   END;
   RAISE NOTICE 'Quantity here is %', quantity;  -- Prints 50
   RETURN quantity;
END;
$$ LANGUAGE plpgsql;
```

Running SQL Commands

You can run SQL commands with PL/pgSQL statements such as `EXECUTE`, `PERFORM`, and `SELECT ... INTO`. For information about the PL/pgSQL statements, see https://www.postgresql.org/docs/12/plpgsql-statements.html.

> **Note** The PL/pgSQL statement `SELECT INTO` is not supported in the `EXECUTE` statement.

PL/pgSQL Plan Caching

A PL/pgSQL function's volatility classification has implications on how WarehousePG caches plans that reference the function. Refer to Function Volatility and Plan Caching in the *WarehousePG Administrator Guide* for information on plan caching considerations for WarehousePG function volatility categories.

When a PL/pgSQL function runs for the first time in a database session, the PL/pgSQL interpreter parses the function's SQL expressions and commands. The interpreter creates a prepared execution plan as each expression and SQL command is first run in the function. The PL/pgSQL interpreter reuses the execution plan for a specific expression and SQL command for the life of the database connection. While this reuse substantially reduces the total amount of time required to parse and generate plans, errors in a specific expression or command cannot be detected until run time when that part of the function is run.

WarehousePG will automatically re-plan a saved query plan if there is any schema change to any relation used in the query, or if any user-defined function used in the query is redefined. This makes the re-use of a prepared plan transparent in most cases.

The SQL commands that you use in a PL/pgSQL function must refer to the same tables and columns on every execution. You cannot use a parameter as the name of a table or a column in an SQL command.

PL/pgSQL caches a separate query plan for each combination of actual argument types in which you invoke a polymorphic function to ensure that data type differences do not cause unexpected failures.

Refer to the PostgreSQL Plan Caching documentation for a detailed discussion of plan caching considerations in the PL/pgSQL language.

PL/pgSQL Examples

The following are examples of PL/pgSQL user-defined functions.

Example: Aliases for Function Parameters

Parameters passed to functions are named with identifiers such as `$1`, `$2`. Optionally, aliases can be declared for `$n` parameter names for increased readability. Either the alias or the numeric identifier can then be used to refer to the parameter value.

There are two ways to create an alias. The preferred way is to give a name to the parameter in the `CREATE FUNCTION` command, for example:

```
CREATE FUNCTION sales_tax(subtotal real) RETURNS real AS $$
BEGIN
   RETURN subtotal * 0.06;
END;
$$ LANGUAGE plpgsql;
```

You can also explicitly declare an alias, using the declaration syntax:

```
name ALIAS FOR $n;
```

This example, creates the same function with the `DECLARE` syntax.

```
CREATE FUNCTION sales_tax(real) RETURNS real AS $$
DECLARE
    subtotal ALIAS FOR $1;
BEGIN
    RETURN subtotal * 0.06;
END;
$$ LANGUAGE plpgsql;
```

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Example: Using the Data Type of a Table Column

When declaring a variable, you can use the `%TYPE` construct to specify the data type of a variable or table column. This is the syntax for declaring a variable whose type is the data type of a table column:

```
name table.column_name%TYPE;
```

You can use the `%TYPE` construct to declare variables that will hold database values. For example, suppose you have a column named `user_id` in your `users` table. To declare a variable named `my_userid` with the same data type as the `users.user_id` column:

```
my_userid users.user_id%TYPE;
```

`%TYPE` is particularly valuable in polymorphic functions, since the data types needed for internal variables may change from one call to the next. Appropriate variables can be created by applying `%TYPE` to the function's arguments or result placeholders.

Example: Composite Type Based on a Table Row

A variable of a composite type is called a row variable. The following syntax declares a composite variable based on table row:

```
name table_name%ROWTYPE;
```

Such a row variable can hold a whole row of a `SELECT` or `FOR` query result, so long as that query's column set matches the declared type of the variable. The individual fields of the row value are accessed using the usual dot notation, for example `rowvar.column`.

Parameters to a function can be composite types (complete table rows). In that case, the corresponding identifier `$n` will be a row variable, and fields can be selected from it, for `example $1.user_id`.

Only the user-defined columns of a table row are accessible in a row-type variable, not the OID or other system columns. The fields of the row type inherit the table's field size or precision for data types such as `char(n)`.

The next example function uses a row variable composite type. Before creating the function, create the table that is used by the function with this command.

```
CREATE TABLE table1 (
  f1 text,
  f2 numeric,
  f3 integer
) distributed by (f1);
```

This `INSERT` command adds data to the table.

```
INSERT INTO table1 values
 ('test1', 14.1, 3),
 ('test2', 52.5, 2),
 ('test3', 32.22, 6),
 ('test4', 12.1, 4) ;
```

This function uses a column `%TYPE` variable and `%ROWTYPE` composite variable based on `table1`.

```
CREATE OR REPLACE FUNCTION t1_calc( name text) RETURNS integer
AS $$
DECLARE
    t1_row   table1%ROWTYPE;
    calc_int table1.f3%TYPE;
BEGIN
    SELECT * INTO t1_row FROM table1 WHERE table1.f1 = $1 ;
    calc_int = (t1_row.f2 * t1_row.f3)::integer ;
    RETURN calc_int ;
END;
$$ LANGUAGE plpgsql VOLATILE;
```

> **Note** The previous function is classified as a `VOLATILE` function because function values could change within a single table scan.

The following `SELECT` command uses the function.

```
select t1_calc( 'test1' );
```

> **Note** The example PL/pgSQL function uses `SELECT` with the `INTO` clause. It is different from the SQL command `SELECT INTO`. If you want to create a table from a `SELECT` result inside a PL/pgSQL function, use the SQL command `CREATE TABLE AS`.

Example: Using a Variable Number of Arguments

You can declare a PL/pgSQL function to accept variable numbers of arguments, as long as all of the optional arguments are of the same data type. You must mark the last argument of the function as `VARIADIC` and declare the argument using an array type. You can refer to a function that includes `VARIADIC` arguments as a variadic function.

For example, this variadic function returns the minimum value of a variable array of numerics:

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```
CREATE FUNCTION mleast (VARIADIC numeric[])
    RETURNS numeric AS $$
  DECLARE minval numeric;
  BEGIN
    SELECT min($1[i]) FROM generate_subscripts( $1, 1) g(i) INTO minval;
    RETURN minval;
END;
$$ LANGUAGE plpgsql;
CREATE FUNCTION

SELECT mleast(10, -1, 5, 4.4);
 mleast
--------
     -1
(1 row)
```

Effectively, all of the actual arguments at or beyond the `VARIADIC` position are gathered up into a one-dimensional array.

You can pass an already-constructed array into a variadic function. This is particularly useful when you want to pass arrays between variadic functions. Specify `VARIADIC` in the function call as follows:

```
SELECT mleast(VARIADIC ARRAY[10, -1, 5, 4.4]);
```

This prevents PL/pgSQL from expanding the function's variadic parameter into its element type.

Example: Using Default Argument Values

You can declare PL/pgSQL functions with default values for some or all input arguments. The default values are inserted whenever the function is called with fewer than the declared number of arguments. Because arguments can only be omitted from the end of the actual argument list, you must provide default values for all arguments after an argument defined with a default value.

For example:

```
CREATE FUNCTION use_default_args(a int, b int DEFAULT 2, c int DEFAULT 3)
    RETURNS int AS $$
DECLARE
    sum int;
BEGIN
    sum := $1 + $2 + $3;
    RETURN sum;
END;
$$ LANGUAGE plpgsql;

SELECT use_default_args(10, 20, 30);
 use_default_args
------------------
               60
(1 row)

SELECT use_default_args(10, 20);
 use_default_args
------------------
               33
(1 row)

SELECT use_default_args(10);
 use_default_args
------------------
               15
(1 row)
```

You can also use the `=` sign in place of the keyword `DEFAULT`.

Example: Using Polymorphic Data Types

PL/pgSQL supports the polymorphic *anyelement*, *anyarray*, *anyenum*, and *anynonarray* types. Using these types, you can create a single PL/pgSQL function that operates on multiple data types. Refer toWarehousePG Data Types for additional information on polymorphic type support in WarehousePG.

A special parameter named `$0` is created when the return type of a PL/pgSQL function is declared as a polymorphic type. The data type of `$0` identifies the return type of the function as deduced from the actual input types.

In this example, you create a polymorphic function that returns the sum of two values:

```
CREATE FUNCTION add_two_values(v1 anyelement,v2 anyelement)
    RETURNS anyelement AS $$
DECLARE
    sum ALIAS FOR $0;
BEGIN
    sum := v1 + v2;
    RETURN sum;
END;
$$ LANGUAGE plpgsql;
```

Run `add_two_values()` providing integer input values:

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```
SELECT add_two_values(1, 2);
 add_two_values
----------------
              3
(1 row)
```

The return type of `add_two_values()` is integer, the type of the input arguments. Now execute `add_two_values()` providing float input values:

```
SELECT add_two_values (1.1, 2.2);
 add_two_values
----------------
            3.3
(1 row)
```

The return type of `add_two_values()` in this case is float.

You can also specify `VARIADIC` arguments in polymorphic functions.

Example: Anonymous Block

This example runs the statements in the `t1_calc()` function from a previous example as an anonymous block using the `DO` command. In the example, the anonymous block retrieves the input value from a temporary table.

```
CREATE TEMP TABLE list AS VALUES ('test1') DISTRIBUTED RANDOMLY;

DO $$
DECLARE
    t1_row   table1%ROWTYPE;
    calc_int table1.f3%TYPE;
BEGIN
    SELECT * INTO t1_row FROM table1, list WHERE table1.f1 = list.column1 ;
    calc_int = (t1_row.f2 * t1_row.f3)::integer ;
    RAISE NOTICE 'calculated value is %', calc_int ;
END $$ LANGUAGE plpgsql ;
```

About Developing PL/pgSQL Procedures

A PL/pgSQL procedure is similar to a PL/pgSQL function. Refer to User-Defined Procedures for more information on procedures in WarehousePG and how they differ from functions.

A PL/pgSQL procedure does not have a return value, and as such can end without a `RETURN` statement. If you wish to use a `RETURN` statement to exit the code early, write just `RETURN` with no expression.

If the PL/pgSQL procedure has output parameters, the final values of the output parameter variables will be returned to the caller.

A PL/pgSQL function, procedure, or `DO` block can call a procedure using `CALL` . Output parameters are handled differently from the way that `CALL` works in plain SQL. Each `INOUT` parameter of the procedure must correspond to a variable in the `CALL` statement, and whatever the procedure returns is assigned back to that variable after it returns. For example:

```
CREATE PROCEDURE triple(INOUT x
int)
LANGUAGE plpgsql
AS $$
BEGIN
    x := x *
3;
END;
$$;

DO $$
DECLARE myvar int := 5;
BEGIN
  CALL
triple(myvar);
  RAISE NOTICE 'myvar = %', myvar;  -- prints
15
END;
$$;
```

About Transaction Management in Procedures

In procedures invoked by the `CALL` command as well as in anonymous code blocks (`DO` command), it is possible to end transactions using the commands `COMMIT` and `ROLLBACK` . A new transaction is started automatically after a transaction is ended using these commands, so there is no separate `START TRANSACTION` command. (Note that `BEGIN` and `END` have different meanings in PL/pgSQL.)

Here is a simple example:

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```
CREATE PROCEDURE
transaction_test1()
LANGUAGE plpgsql
AS $$
BEGIN
    FOR i IN 0..9
LOOP
        INSERT INTO test1 (a) VALUES
(i);
        IF i % 2 = 0
THEN
            COMMIT;
        ELSE
            ROLLBACK;
        END IF;
    END LOOP;
END;
$$;

CALL transaction_test1();
```

A new transaction starts out with default transaction characteristics such as transaction isolation level. In cases where transactions are committed in a loop, it might be desirable to start new transactions automatically with the same characteristics as the previous one. The commands COMMIT AND CHAIN and ROLLBACK AND CHAIN accomplish this.

Transaction control is only possible in `CALL` or `DO` invocations from the top level or nested `CALL` or `DO` invocations without any other intervening command. For example, if the call stack is `CALL proc1()` → `CALL proc2()` → `CALL proc3()`, then the second and third procedures can perform transaction control actions. But if the call stack is `CALL proc1()` → `SELECT func2()` → `CALL proc3()`, the last procedure cannot perform transaction control because of the `SELECT` in between.

References

The PostgreSQL documentation about PL/pgSQL is at https://www.postgresql.org/docs/12/plpgsql.html

Also, see the CREATE FUNCTION command in the *WarehousePG Reference Guide*.

For a summary of built-in WarehousePG functions, see Summary of Built-in Functions in the *WarehousePG Reference Guide*. For information about using WarehousePG functions see "SQL: Querying Data" in the *WarehousePG Administrator Guide*

For information about porting Oracle functions, see https://www.postgresql.org/docs/12/plpgsql-porting.html. For information about installing and using the Oracle compatibility functions with WarehousePG, see "Oracle Compatibility Functions" in the *WarehousePG Utility Guide*.

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4.8 Working with External Data

Both external and foreign tables provide access to data stored in data sources outside of WarehousePG as if the data were stored in regular database tables. You can read data from and write data to external and foreign tables.

> **Important** WarehousePG 7 internally converts external tables to foreign tables, and internally operates on and represents the table using the foreign table data structures and catalog. Refer toUnderstanding the External Table to Foreign Table Mapping for detailed information about this conversion, and its runtime implications.

Parent topic: WarehousePG Administrator Guide

About Foreign Tables

A foreign table is a WarehousePG table backed with data that resides outside of the database. Foreign tables are often used to load and unload database data. You can both read from and write to the same foreign table. You can use foreign tables in SQL commands just as you would a regular database table. For example, you can `SELECT`, `INSERT`, and `JOIN` foreign tables with other WarehousePG tables.

Refer to Accessing External Data with Foreign Tables for more information about accessing external data using foreign tables.

About External Tables

An external table is different kind of WarehousePG table backed with data that resides outside of the database. External tables are often used to load and unload database data. You create a readable external table to read data from the external data source and create a writable external table to write data to the external source. You can use external tables in SQL commands just as you would a regular database table. For example, you can `SELECT` (readable external table), `INSERT` (writable external table), and `JOIN` external tables with other WarehousePG tables.

Refer to Acessing External Data with External Tables for more information about using external tables to access external data.

About gpfdist External Tables

You can use the `gpfdist` file server utility and external tables to serve up external data to WarehousePG. When external data is served by `gpfdist`, all segments in the WarehousePG cluster can read or write external table data in parallel. Refer to Using the WarehousePG Parallel File Server (gpfdist) for more information.

About Web-Based External Tables

Web-based external tables provide access to data served by an HTTP server or an operating system process. See Creating and Using External Web Tables for more about web-based tables.

About Accessing External Data with pxf

Data managed by your organization may already reside in external sources such as Hadoop, object stores, and other SQL databases. The WarehousePG Platform Extension Framework (PXF) provides access to this external data via built-in connectors that map an external data source to a WarehousePG table definition. Refer to Accessing External Data with PXF for more information about using PXF.

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4.8.1 Accessing External Data with Foreign Tables

WarehousePG implements portions of the SQL/MED specification, allowing you to access data that resides outside of WarehousePG using regular SQL queries. Such data is referred to as *foreign* or external data.

You can access foreign data with help from a *foreign-data wrapper*. A foreign-data wrapper is a library that communicates with a remote data source. This library hides the source-specific connection and data access details.

The WarehousePG distribution includes the postgres_fdw foreign data wrapper. You can also download and install the EDB-provided module whpg_fdw.

If none of the existing PostgreSQL or WarehousePG foreign-data wrappers suit your needs, you can write your own as described in Writing a Foreign Data Wrapper.

To access foreign data, you create a *foreign server* object, which defines how to connect to a particular remote data source according to the set of options used by its supporting foreign-data wrapper. Then you create one or more *foreign tables*, which define the structure of the remote data. A foreign table can be used in queries just like a normal table, but a foreign table has no storage in the WarehousePG server. Whenever a foreign table is accessed, WarehousePG asks the foreign-data wrapper to fetch data from, or update data in (if supported by the wrapper), the remote source.

Accessing remote data may require authenticating to the remote data source. This information can be provided by a *user mapping*, which can provide additional data such as a user name and password based on the current WarehousePG role.

For additional information, refer to the CREATE FOREIGN DATA WRAPPER, CREATE SERVER, CREATE USER MAPPING, and CREATE FOREIGN TABLE SQL reference pages.

Using Foreign-Data Wrappers with WarehousePG

Most PostgreSQL foreign-data wrappers should work with WarehousePG. However, PostgreSQL foreign-data wrappers connect only through the WarehousePG coordinator by default and do not access the WarehousePG segment instances directly.

WarehousePG adds an `mpp_execute` option to FDW-related SQL commands. If the foreign-data wrapper supports it, you can specify `mpp_execute '<value>'` in the `OPTIONS` clause when you create the FDW, server, or foreign table to identify the WarehousePG host from which the foreign-data wrapper reads or writes data. Valid `<value>` s are:

- `coordinator` (the default) - Read or write data from the coordinator host.
- `any` - Read data from either the coordinator host or any one segment, depending on which path costs less.
- `all segments` - Read or write data from all segments. If a foreign-data wrapper supports this value, for correct results it should have a policy that matches segments to data.

(A PostgreSQL foreign-data wrapper may work with the various `mpp_execute` option settings, but the results are not guaranteed to be correct. For example, a segment may not be able to connect to the foriegn server, or segments may receive overlapping results resulting in duplicate rows.)

Parent topic: Working with External Data

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4.8.1.1 Writing a Foreign Data Wrapper

This chapter outlines how to write a new foreign-data wrapper.

All operations on a foreign table are handled through its foreign-data wrapper (FDW), a library that consists of a set of functions that the core WarehousePG server calls. The foreign-data wrapper is responsible for fetching data from the remote data store and returning it to the WarehousePG executor. If updating foreign-data is supported, the wrapper must handle that, too.

The foreign-data wrappers included in the WarehousePG open source github repository are good references when trying to write your own. You may want to examine the source code for thefile_fdw and postgres_fdw modules in the `contrib/` directory. The CREATE FOREIGN DATA WRAPPER reference page also provides some useful details.

> **Note** The SQL standard specifies an interface for writing foreign-data wrappers. WarehousePG does not implement that API, however, because the effort to accommodate it into WarehousePG would be large, and the standard API hasn't yet gained wide adoption.

Parent topic: Accessing External Data with Foreign Tables

Requirements

When you develop with the WarehousePG foreign-data wrapper API:

- You must develop your code on a system with the same hardware and software architecture as that of your WarehousePG hosts.
- Your code must be written in a compiled language such as C, using the version-1 interface. For details on C language calling conventions and dynamic loading, refer toC Language Functions in the PostgreSQL documentation.
- Symbol names in your object files must not conflict with each other nor with symbols defined in the WarehousePG server. You must rename your functions or variables if you get error messages to this effect.
- Review the foreign table introduction described in Accessing External Data with Foreign Tables.

Known Issues and Limitations

The WarehousePG 7 foreign-data wrapper implementation has the following known issues and limitations:

- WarehousePG supports all values of the `mpp_execute` option value for foreign table scans only. WarehousePG supports parallel write operations only when `mpp_execute` is set to `'all segments'`; WarehousePG initiates write operations through the coordinator for all other `mpp_execute` settings. See WarehousePG Considerations.

Header Files

The WarehousePG header files that you may use when you develop a foreign-data wrapper are located in the `gpdb/src/include/` directory (when developing against the WarehousePG open source github repository), or installed in the `$GPHOME/include/postgresql/server/` directory (when developing against a WarehousePG installation):

- `foreign/fdwapi.h` - FDW API structures and callback function signatures
- `foreign/foreign.h` - foreign-data wrapper helper structs and functions
- `catalog/pg_foreign_table.h` - foreign table definition
- `catalog/pg_foreign_server.h` - foreign server definition

Your FDW code may also be dependent on header files and libraries required to access the remote data store.

Foreign Data Wrapper Functions

The developer of a foreign-data wrapper must implement an SQL-invokable *handler* function, and optionally an SQL-invokable *validator* function. Both functions must be written in a compiled language such as C, using the version-1 interface.

The *handler* function simply returns a struct of function pointers to callback functions that will be called by the WarehousePG planner, executor, and various maintenance commands. The *handler* function must be registered with WarehousePG as taking no arguments and returning the special pseudo-type `fdw_handler`. For example:

```
CREATE FUNCTION NEW_fdw_handler()
  RETURNS fdw_handler
  AS 'MODULE_PATHNAME'
LANGUAGE C STRICT;
```

Most of the effort in writing a foreign-data wrapper is in implementing the callback functions. The FDW API callback functions, plain C functions that are not visible or callable at the SQL level, are described inForeign Data Wrapper Callback Functions.

The *validator* function is responsible for validating options provided in `CREATE` and `ALTER` commands for its foreign-data wrapper, as well as foreign servers, user mappings, and foreign tables using the wrapper. The*validator* function must be registered as taking two arguments, a text array containing the options to be validated, and an OID representing the type of object with which the options are associated. For example:

```
CREATE FUNCTION NEW_fdw_validator( text[], oid )
  RETURNS void
  AS 'MODULE_PATHNAME'
LANGUAGE C STRICT;
```

The OID argument reflects the type of the system catalog that the object would be stored in, one of `ForeignDataWrapperRelationId`, `ForeignServerRelationId`, `UserMappingRelationId`, or `ForeignTableRelationId`. If no *validator* function is supplied by a foreign data wrapper, WarehousePG does not check option validity at object creation time or object alteration time.

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Foreign Data Wrapper Callback Functions

The foreign-data wrapper API defines callback functions that WarehousePG invokes when scanning and updating foreign tables. The API also includes callbacks for performing explain and analyze operations on a foreign table.

The *handler* function of a foreign-data wrapper returns a `palloc`'d `FdwRoutine` struct containing pointers to callback functions described below. The `FdwRoutine` struct is located in the `foreign/fdwapi.h` header file, and is defined as follows:

```
/*
 * FdwRoutine is the struct returned by a foreign-data wrapper's handler
 * function.  It provides pointers to the callback functions needed by the
 * planner and executor.
 *
 * More function pointers are likely to be added in the future.  Therefore
 * it's recommended that the handler initialize the struct with
 * makeNode(FdwRoutine) so that all fields are set to NULL.  This will
 * ensure that no fields are accidentally left undefined.
 */
typedef struct FdwRoutine
{
    NodeTag     type;

    /* Functions for scanning foreign tables */
    GetForeignRelSize_function GetForeignRelSize;
    GetForeignPaths_function GetForeignPaths;
    GetForeignPlan_function GetForeignPlan;
    BeginForeignScan_function BeginForeignScan;
    IterateForeignScan_function IterateForeignScan;
    ReScanForeignScan_function ReScanForeignScan;
    EndForeignScan_function EndForeignScan;

    /*
     * Remaining functions are optional.  Set the pointer to NULL for any that
     * are not provided.
     */

    /* Functions for updating foreign tables */
    AddForeignUpdateTargets_function AddForeignUpdateTargets;
    PlanForeignModify_function PlanForeignModify;
    BeginForeignModify_function BeginForeignModify;
    ExecForeignInsert_function ExecForeignInsert;
    ExecForeignUpdate_function ExecForeignUpdate;
    ExecForeignDelete_function ExecForeignDelete;
    EndForeignModify_function EndForeignModify;
    IsForeignRelUpdatable_function IsForeignRelUpdatable;

    /* Support functions for EXPLAIN */
    ExplainForeignScan_function ExplainForeignScan;
    ExplainForeignModify_function ExplainForeignModify;

    /* Support functions for ANALYZE */
    AnalyzeForeignTable_function AnalyzeForeignTable;
} FdwRoutine;
```

You must implement the scan-related functions in your foreign-data wrapper; implementing the other callback functions is optional.

Scan-related callback functions include:

Callback Signature	Description
`void GetForeignRelSize (PlannerInfo *root, RelOptInfo *baserel, Oid foreigntableid)`	Obtain relation size estimates for a foreign table. Called at the beginning of planning for a query on a foreign table.
`void GetForeignPaths (PlannerInfo *root, RelOptInfo *baserel, Oid foreigntableid)`	Create possible access paths for a scan on a foreign table. Called during query planning. Note: A WarehousePG Database-compatible FDW must call `create_foreignscan_path()` in its `GetForeignPaths()` callback function.
`ForeignScan * GetForeignPlan (PlannerInfo *root, RelOptInfo *baserel, Oid foreigntableid, ForeignPath *best_path, List *tlist, List *scan_clauses)`	Create a `ForeignScan` plan node from the selected foreign access path. Called at the end of query planning.
`void BeginForeignScan (ForeignScanState *node, int eflags)`	Begin running a foreign scan. Called during executor startup.

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Callback Signature	Description
`TupleTableSlot * IterateForeignScan (ForeignScanState *node)`	Fetch one row from the foreign source, returning it in a tuple table slot; return NULL if no more rows are available.
`void ReScanForeignScan (ForeignScanState *node)`	Restart the scan from the beginning.
`void EndForeignScan (ForeignScanState *node)`	End the scan and release resources.

If a foreign data wrapper supports writable foreign tables, it should provide the update-related callback functions that are required by the capabilities of the FDW. Update-related callback functions include:

Callback Signature	Description
`void AddForeignUpdateTargets (Query *parsetree, RangeTblEntry *target_rte, Relation target_relation)`	Add additional information in the foreign table that will be retrieved during an update or delete operation to identify the exact row on which to operate.
`List * PlanForeignModify (PlannerInfo *root, ModifyTable *plan, Index resultRelation, int subplan_index)`	Perform additional planning actions required for an insert, update, or delete operation on a foreign table, and return the information generated.
`void BeginForeignModify (ModifyTableState *mtstate, ResultRelInfo *rinfo, List *fdw_private, int subplan_index, int eflags)`	Begin executing a modify operation on a foreign table. Called during executor startup.
`TupleTableSlot * ExecForeignInsert (EState *estate, ResultRelInfo *rinfo, TupleTableSlot *slot, TupleTableSlot *planSlot)`	Insert a single tuple into the foreign table. Return a slot containing the data that was actually inserted, or NULL if no row was inserted.
`TupleTableSlot * ExecForeignUpdate (EState *estate, ResultRelInfo *rinfo, TupleTableSlot *slot, TupleTableSlot *planSlot)`	Update a single tuple in the foreign table. Return a slot containing the row as it was actually updated, or NULL if no row was updated.
`TupleTableSlot * ExecForeignDelete (EState *estate, ResultRelInfo *rinfo, TupleTableSlot *slot, TupleTableSlot *planSlot)`	Delete a single tuple from the foreign table. Return a slot containing the row that was deleted, or NULL if no row was deleted.
`void EndForeignModify (EState *estate, ResultRelInfo *rinfo)`	End the update and release resources.
`int IsForeignRelUpdatable (Relation rel)`	Report the update operations supported by the specified foreign table.

Refer to Foreign Data Wrapper Callback Routines in the PostgreSQL documentation for detailed information about the inputs and outputs of the FDW callback functions.

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Foreign Data Wrapper Helper Functions

The FDW API exports several helper functions from the WarehousePG core server so that authors of foreign-data wrappers have easy access to attributes of FDW-related objects, such as options provided when the user creates or alters the foreign-data wrapper, server, or foreign table. To use these helper functions, you must include `foreign.h` header file in your source file:

```
#include "foreign/foreign.h"
```

The FDW API includes the helper functions listed in the table below. Refer to Foreign Data Wrapper Helper Functions in the PostgreSQL documentation for more information about these functions.

Helper Signature	Description
`ForeignDataWrapper * GetForeignDataWrapper(Oid fdwid);`	Returns the `ForeignDataWrapper` object for the foreign-data wrapper with the given OID.
`ForeignDataWrapper * GetForeignDataWrapperByName(const char *name, bool missing_ok);`	Returns the `ForeignDataWrapper` object for the foreign-data wrapper with the given name.
`ForeignServer * GetForeignServer(Oid serverid);`	Returns the `ForeignServer` object for the foreign server with the given OID.
`ForeignServer * GetForeignServerByName(const char *name, bool missing_ok);`	Returns the `ForeignServer` object for the foreign server with the given name.
`UserMapping * GetUserMapping(Oid userid, Oid serverid);`	Returns the `UserMapping` object for the user mapping of the given role on the given server.
`ForeignTable * GetForeignTable(Oid relid);`	Returns the `ForeignTable` object for the foreign table with the given OID.
`List * GetForeignColumnOptions(Oid relid, AttrNumber attnum);`	Returns the per-column FDW options for the column with the given foreign table OID and attribute number.

WarehousePG Considerations

A WarehousePG user can specify the `mpp_execute` option when they create or alter a foreign table, foreign server, or foreign data wrapper. A WarehousePG-compatible foreign-data wrapper examines the `mpp_execute` option value and uses it to determine where to request or send data - from the `coordinator` (the default), `any` (coordinator or any one segment), or `all segments` (parallel read/write).

WarehousePG supports all `mpp_execute` settings for a scan.

WarehousePG supports parallel write when `mpp_execute 'all segments"` is set. For all other `mpp_execute` settings, WarehousePG executes write/update operations initiated by a foreign data wrapper on the WarehousePG coordinator node.

> **Note** When `mpp_execute 'all segments'` is set, WarehousePG creates the foreign table with a random partition policy. This enables a foreign data wrapper to write to a foreign table from all segments.

The following scan code snippet probes the `mpp_execute` value associated with a foreign table:

```
ForeignTable *table = GetForeignTable(foreigntableid);
if (table->exec_location == FTEXECLOCATION_ALL_SEGMENTS)
{
    ...
}
else if (table->exec_location == FTEXECLOCATION_ANY)
{
    ...
}
else if (table->exec_location == FTEXECLOCATION_COORDINATOR)
{
    ...
}
```

If the foreign table was not created with an `mpp_execute` option setting, the `mpp_execute` setting of the foreign server, and then the foreign data wrapper, is probed and used. If none of the foreign-data-related objects has an `mpp_execute` setting, the default setting is `coordinator`.

If a foreign-data wrapper supports `mpp_execute 'all'`, it will implement a policy that matches WarehousePG segments to data. So as not to duplicate data retrieved from the remote, the FDW on each segment must be able to establish which portion of the data is their responsibility. An FDW may use the segment identifier and the number of segments to help make this determination. The following code snippet demonstrates how a foreign-data wrapper may retrieve the segment number and total number of segments:

```
int segmentNumber = GpIdentity.segindex;
int totalNumberOfSegments = getgpsegmentCount();
```

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Building a Foreign Data Wrapper Extension with PGXS

You compile the foreign-data wrapper functions that you write with the FDW API into one or more shared libraries that the WarehousePG server loads on demand.

You can use the PostgreSQL build extension infrastructure (PGXS) to build the source code for your foreign-data wrapper against a WarehousePG installation. This framework automates common build rules for simple modules. If you have a more complicated use case, you will need to write your own build system.

To use the PGXS infrastructure to generate a shared library for your FDW, create a simple `Makefile` that sets PGXS-specific variables.

> **Note** Refer to Extension Building Infrastructure in the PostgreSQL documentation for information about the `Makefile` variables supported by PGXS.

For example, the following `Makefile` generates a shared library in the current working directory named `base_fdw.so` from two C source files, base_fdw_1.c and base_fdw_2.c:

```
MODULE_big = base_fdw
OBJS = base_fdw_1.o base_fdw_2.o

PG_CONFIG = pg_config
PGXS := $(shell $(PG_CONFIG) --pgxs)

PG_CPPFLAGS = -I$(shell $(PG_CONFIG) --includedir)
SHLIB_LINK = -L$(shell $(PG_CONFIG) --libdir)
include $(PGXS)
```

A description of the directives used in this `Makefile` follows:

- `MODULE_big` - identifes the base name of the shared library generated by the `Makefile`
- `PG_CPPFLAGS` - adds the WarehousePG installation `include/` directory to the compiler header file search path
- `SHLIB_LINK` adds the WarehousePG installation library directory (`$GPHOME/lib/`) to the linker search path
- The `PG_CONFIG` and `PGXS` variable settings and the `include` statement are required and typically reside in the last three lines of the `Makefile` .

To package the foreign-data wrapper as a WarehousePG extension, you create script (`newfdw--version.sql`) and control (`newfdw.control`) files that register the FDW *handler* and *validator* functions, create the foreign data wrapper, and identify the characteristics of the FDW shared library file.

> **Note** Packaging Related Objects into an Extension in the PostgreSQL documentation describes how to package an extension.

Example foreign-data wrapper extension script file named `base_fdw--1.0.sql` :

```
CREATE FUNCTION base_fdw_handler()
  RETURNS fdw_handler
  AS 'MODULE_PATHNAME'
LANGUAGE C STRICT;

CREATE FUNCTION base_fdw_validator(text[], oid)
  RETURNS void
  AS 'MODULE_PATHNAME'
LANGUAGE C STRICT;

CREATE FOREIGN DATA WRAPPER base_fdw
  HANDLER base_fdw_handler
  VALIDATOR base_fdw_validator;
```

Example FDW control file named `base_fdw.control` :

```
# base_fdw FDW extension
comment = 'base foreign-data wrapper implementation; does not do much'
default_version = '1.0'
module_pathname = '$libdir/base_fdw'
relocatable = true
```

When you add the following directives to the `Makefile` , you identify the FDW extension control file base name (`EXTENSION`) and SQL script (`DATA`):

```
EXTENSION = base_fdw
DATA = base_fdw--1.0.sql
```

Running `make install` with these directives in the `Makefile` copies the shared library and FDW SQL and control files into the specified or default locations in your WarehousePG installation (`$GPHOME`).

Deployment Considerations

You must package the FDW shared library and extension files in a form suitable for deployment in a WarehousePG cluster. When you construct and deploy the package, take into consideration the following:

- The FDW shared library must be installed to the same file system location on the coordinator host and on every segment host in the WarehousePG cluster. You specify this location in the `.control` file. This location is typically the `$GPHOME/lib/postgresql/` directory.
- The FDW `.sql` and `.control` files must be installed to the `$GPHOME/share/postgresql/extension/` directory on the coordinator host and on every segment host in the WarehousePG cluster.
- The `gpadmin` user must have permission to traverse the complete file system path to the FDW shared library file and extension files.

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4.8.2 Accessing External Data with External Tables

examples originalFilePath: >- https://github.com/warehouse-pg/whpg-docs/blob/main/docs/docs/7x/admin_guide/external/external-tables/index.md editTarget: originalFilePath

---

External tables enable you to access external data as if it were a regular database table. They are often used to move data into and out of a WarehousePG, and can utilize WarehousePG parallelism by using the resources of all WarehousePG segments to load or unload data.

When you create an external table definition, you specify the structure and format of the data, the data access *protocol*, the location of the external data source, and other protocol-specific or format-specific options.

> **Important** WarehousePG 7 internally converts external tables to foreign tables, and internally operates on and represents the table using the foreign table data structures and catalog. Refer to Understanding the External Table to Foreign Table Mapping for detailed information about this conversion, and its runtime implications.

Parent topic: Working with External Data

About the External Table Data Access Protocols

An external table protocol identifies the data access method for an external data source. WarehousePG supports the following built-in (automatically-enabled) and opt-in (you enable) external table protocols:

Protocol Name	Description	Type
`file://`	Use to access external data files on segment hosts that the WarehousePG superuser (`gpadmin`) can access. Refer to file:// Protocol.	Built-in
`gpfdist://`	Use to serve external data files to all WarehousePG segments in parallel. See gpfdist:// Protocol.	Built-in
`gpfdists://`	The secure version of `gpfdist` . See gpfdists:// Protocol.	Built-in
`pxf://`	Use to access external object store systems (Azure, Google Cloud Storage, Minio, S3-compatible), Hadoop systems (HDFS, Hive, HBase), network file systems, and SQL databases with the WarehousePG Platform Extension Framework (PXF). See pxf:// Protocol.	Opt-in
`s3://`	Use to access files in an Amazon S3 bucket. See s3:// Protocol.	Opt-in

A third party can also create a custom protocol that connects WarehousePG to new external data sources. Refer to Creating a Custom Protocol for more information.

The opt-in/custom and built-in protocols differ in these ways:

- You must register opt-in and custom protocols. Built-in protocols are always available and cannot be unregistered.
- When you register an opt-in or custom protocol, WarehousePG adds a row to the `pg_extprotocol` catalog table to specify the handler functions that implement the protocol. The built-in protocols are not represented in this table.
- You must have installed the opt-in or custom protocol's shared libraries on all WarehousePG hosts. The built-in protocols have no additional libraries to install.
- You use `GRANT [SELECT | INSERT | ALL] ON PROTOCOL <name>` to grant users permissions on opt-in and custom protocols. To allow (or deny) users access to the built-in protocols, you use the `CREATE ROLE` or `ALTER ROLE` commands to add the `CREATEEXTTABLE` (or `NOCREATEEXTTABLE`) attribute to each user's role.

About External Table Operations

WarehousePG provides both readable (CREATE EXTERNAL TABLE) and writable (`CREATE WRITABLE EXTERNAL TABLE`) external tables.

Readable external tables are typically used for data loading, and allow only SELECT operations. They support:

- Basic extraction, transformation, and loading (ETL) tasks common in data warehousing
- Reading external table data in parallel from multiple WarehousePG segment instances, to optimize large load operations
- Filter pushdown. If a query contains a `WHERE` clause, it may be passed to the external data source. Refer to the gp_external_enable_filter_pushdown server configuration parameter discussion for more information. Note that this feature is currently supported only with the `pxf` protocol (see pxf:// Protocol).

Writable external tables are typically used for data unloading, and allow only INSERT operations. They support:

- Selecting data from database tables to insert into the writable external table
- Sending data to an application as a stream of data. For example, unload data from WarehousePG and send it to an application that connects to another database or ETL tool to load the data elsewhere.

About the External Table Types

External tables are typically file-based or web-based:

- Regular (file-based) external tables can access static flat files. Regular external tables are rescannable: the data is static while the query runs.
- Web (web-based) external tables access dynamic data sources, either on a web server with the `http://` protocol or by running OS commands or scripts. External web tables are not rescannable, the data can change while the query runs. Refer to Creating and Using External Web Tables for more information.

The `pxf://` protocol can also access other types of external data, such as SQL databases.

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Creating an External Table

When you create an external table definition, you specify the structure and format of the data, the access protocol, the location of the external data source, and other protocol-specific or format-specific options.

Examples for Creating External Tables provides examples for different data types and different built-in protocols.

> **Important** After you create an external table, you must operate on the table using `ALTER EXTERNAL TABLE` and `DROP EXTERNAL TABLE` commands. WarehousePG does not recommend mixing and matching external table and foreign table syntaxes for table maintenance operations.

Other Considerations

WarehousePG backup and restore operations back up and restore only external and external web table *definitions*, not the data source data.

By default, if external table data contains an error, the command fails and no data loads into the target database table. See Handling Errors in External Table Data for more information.

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4.8.2.1 Understanding the External Table to Foreign Table Mapping

WarehousePG 7 uses the built-in `gp_exttable_fdw` foreign-data wrapper module to internally convert an external table that you define with the CREATE EXTERNAL TABLE command to a foreign table.

In the foreign data paradigm, a foreign-data wrapper (FDW) provides access to an external data source. A foreign server object associated with a specific FDW defines the connection details to a particular remote data source. A foreign table specifies the foreign server with which to access the remote data source. The foreign table also defines the structure of the remote data, just as you would define with an external table. Refer to Accessing External Data with Foreign Tables for more information about how to manage external data with FDWs.

WarehousePG internally maps the information that you provide in the `CREATE [WRITABLE] EXTERNAL TABLE` command to foreign data objects as follows:

Foreign Data Object	Name/Value	Comments
foreign-data wrapper	`gp_exttable_fdw`	WarehousePG maps all external tables that you create with the `CREATE [WRITABLE] EXTERNAL TABLE` command to the `gp_exttable_fdw` FDW. This FDW handles the external to foreign table conversion.
foreign server	`gp_exttable_server`	WarehousePG maps all external tables that you create with the `CREATE [WRITABLE] EXTERNAL TABLE` command to the `gp_exttable_server` server.
foreign table	`<external_table_name>`	WarehousePG maps an external table that you create with the `CREATE [WRITABLE] EXTERNAL TABLE` command to a foreign table of the same name.

When `gp_exttable_fdw` internally creates the foreign table, it maps the clauses and keywords that you provide in the `CREATE [WRITABLE] EXTERNAL TABLE` command to specific FDW options. In cases where no direct mapping exists, or where there is no equivalent external table clause, default FDW option values are provided.

The external table clause to foreign table option mapping follows:

CREATE EXTERNAL TABLE Clause	FDW Option(s) and Value(s)	Description	
CREATE EXTERNAL TABLE	`is_writable 'false'`	Readable external tables are not writable.	
CREATE WRITABLE EXTERNAL TABLE	`is_writable 'true'`	Writable external tables are writable and alterable.	
`LOCATION ('<location>' [, ...])`	`location_uris '<location>'`	The location of the external data. `gp_exttable_fdw` uses a pipe (`	`) character to separate locations when you provide more than one.
`FORMAT 'TEXT'`	`format 'text'`	The external data is text format.	
`FORMAT 'CSV'`	`format 'csv'`	The external data is comma-separated value format.	
`FORMAT 'CUSTOM'`	`format 'custom' formatter '<name>'`	The external data is of a custom format, and WarehousePG uses the specified formatter to parse the data.	
formatting options	`delimiter <value>` `escape <value>` `"null" <value>` `<option1> <value>` `...`	Format-dependent formatting options.	
`OPTIONS <key> '<value>' [, ...]`	`<key> <value>` `...`	The data access protocol-specific options.	
`ENCODING <encoding>`	`encoding '<encoding_str>'`	The table encoding (string).	
`LOG ERRORS`	`log_errors 'enable'`	Log errors to an error log. `gp_exttable_fdw` sets this FDW option to `log_errors 'disable'` when the `LOG ERRORS` clause is not provided.	
`LOG ERRORS PERSISTENTLY`	`log_errors 'persistently'`	Log errors to a persistent error log. `gp_exttable_fdw` sets this FDW option to `log_errors 'disable'` when the `LOG ERRORS` clause is not provided.	
`SEGMENT REJECT LIMIT <num_or_pct>`	`reject_limit '<num>' reject_limit_type '<type>'`	The number of errored rows (`<type>` is `rows`) or the errored row percentage (`<type>` is `percentage`) allowed.	
n/a	`execute_on 'ALL_SEGMENTS'`	Utilize the parallel processing inherent in WarehousePG.	

Implications

Because WarehousePG 7 converts an external table to a foreign table and uses foreign table structures and catalogs to internally represent external tables:

- External tables are included in the foreign table catalogs. Use the pg_foreign_table system catalog table and the `ftoptions` column to view external table definitions.
- Certain command output and error, detail, and notice messages about external tables refer to the table as a foreign table.
- External tables are included when you list or examine foreign tables (for example, the `\det psql` meta-command).

Example

Given the following external table definition:

```
CREATE EXTERNAL TABLE ext_expenses ( name text, date date, amount float4, category text, desc1 varchar )
  LOCATION ('gpfdist://etlhost-1:8081/*.txt', 'gpfdist://etlhost-2:8082/*.txt')
FORMAT 'TEXT' ( DELIMITER '|' NULL ' ' )
LOG ERRORS SEGMENT REJECT LIMIT 5;
```

`gp_exttable_fdw` creates a foreign table whose `psql` `\d+` output follows:

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```
\d+ ext_expenses
                                        Foreign table "public.ext_expenses"
  Column  |       Type        | Collation | Nullable | Default | FDW options | Storage  | Stats target | Description
----------+-------------------+-----------+----------+---------+-------------+----------+--------------+-------------
 name     | text              |           |          |         |             | extended |              |
 date     | date              |           |          |         |             | plain    |              |
 amount   | real              |           |          |         |             | plain    |              |
 category | text              |           |          |         |             | extended |              |
 desc1    | character varying |           |          |         |             | extended |              |
FDW options: (format 'text', delimiter '|', "null" ' ', escape E'\\', location_uris 'gpfdist://etlhost-1:8081/\*.txt|'gpfdist://etlhost-2:8082/\*.txt', execute_on
'ALL_SEGMENTS', reject_limit '5', reject_limit_type 'rows', log_errors 'enable', encoding 'UTF8', is_writable 'false')
```

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4.8.2.2 About Changes to External Tables in WarehousePG 7

This topic describes the external table implementation and changes in WarehousePG 7, and is geared towards existing users of WarehousePG 6. WarehousePG 7 converts an external table that you define with the CREATE EXTERNAL TABLE command into a foreign table, and internally operates on and represents the table using the foreign table data structures and catalog.

(See also Understanding the External Table to Foreign Table Mapping for detailed information about the external table to foreign table conversion, and its runtime implications.)

Parent topic: Accessing External Data with External Tables

What's the Same?

If you used external tables in WarehousePG 6, the underlying functionality has not changed in WarehousePG 7. The following external table features and behaviors remain the same in WarehousePG 7:

- WarehousePG 7 fully supports the external table SQL command syntax of WarehousePG 6.
- WarehousePG 7 fully supports external table access to remote data sources via all existing protocols (`file`, `gpdist`, `pxf`, and `s3`).
- You must create separate tables to read from (`CREATE EXTERNAL TABLE`) and write to (`CREATE WRITABLE EXTERNAL TABLE`) the same external data location.
- The pg_exttable system catalog (now a view) provides the same information.

What Has Changed?

Note the following differences in the WarehousePG 7 external table implementation compared to WarehousePG 6:

- WarehousePG 7 uses foreign table data structures and catalogs to internally represent external tables. Use the pg_foreign_table system catalog table and the `ftoptions` column to view the table definition.
- A `pg_tables` query no longer returns external tables in the query results.
- The `pg_class.relkind` of an external table is now `f` (was previously `r`).
- The pg_exttable system catalog is now a view.
- In addition to `pg_exttable`, you can use the following query to list all of the foreign tables that were created using the `CREATE [WRITABLE] EXTERNAL TABLE` command:

```
SELECT * FROM pg_foreign_table ft
  JOIN pg_foreign_server fs ON ft.ftserver = fs.oid
  WHERE srvname = 'gp_exttable_server';
```

- Because an external table is internally represented as a foreign table:
  - Every external table is associated with the `gp_exttable_fdw` foreign-data wrapper.
  - Every external table is associated with the `gp_exttable_server` foreign server.
  - Certain command output and error, detail, and notice messages about external tables refer to the table as a foreign table.
  - External tables are included in the foreign table catalogs, for example pg_foreign_table.
  - External tables are included when you list or examine foreign tables (for example, the `\det` `psql` meta-command).
- External table-specific information displayed in `psql` `\dE+` output has changed; the relation `Type` of an external table is now `foreign table`. Example:

```
\dE
               List of relations
 Schema |     Name     |     Type      |  Owner
--------+--------------+---------------+---------
 public | ext_expenses | foreign table | gpadmin
```

- External table-specific information displayed in `psql` `\d+ <external_table_name>` output has changed; it now displays in foreign table format. For this example `CREATE EXTERNAL TABLE` call:

```
CREATE EXTERNAL TABLE ext_expenses ( name text, date date, amount float4, category text, desc1 varchar )
  LOCATION ('gpfdist://etlhost-1:8081/*.txt', 'gpfdist://etlhost-2:8082/*.txt')
FORMAT 'TEXT' ( DELIMITER '|' NULL ' ' )
LOG ERRORS SEGMENT REJECT LIMIT 5;
```

The example `\d+` output follows:

```
\d+ ext_expenses
                                    Foreign table "public.ext_expenses"
  Column  |       Type        | Collation | Nullable | Default | FDW options | Storage  | Stats target | Description
----------+-------------------+-----------+----------+---------+-------------+----------+--------------+-------------
 name     | text              |           |          |         |             | extended |              |
 date     | date              |           |          |         |             | plain    |              |
 amount   | real              |           |          |         |             | plain    |              |
 category | text              |           |          |         |             | extended |              |
 desc1    | character varying |           |          |         |             | extended |              |
FDW options: (format 'text', delimiter '|', "null" ' ', escape E'\\', location_uris 'gpfdist://etlhost-1:8081/\*.txt|'gpfdist://etlhost-2:8082/\*.txt',
execute_on 'ALL_SEGMENTS', reject_limit '5', reject_limit_type 'rows', log_errors 'enable', encoding 'UTF8', is_writable 'false')
```

- The `EXPLAIN` output for a query including an external table previously returned the text `External Scan`. `EXPLAIN` now returns `Foreign Scan` in this scenario.

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Additional Considerations

Additional factors to consider:

- Even though an external table is internally represented as a foreign table, you cannot both read from and write to the same external table.
- You must change any scripts that you wrote that depend on external table DDL or `psql` `\dE` or `\d+` output.
- WarehousePG 7 dumps and restores the DDL of external tables using foreign table syntax.

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4.8.2.3 file:// Protocol

The `file://` protocol is used in a URI that specifies the location of an operating system file. External tables that you create that specify the `file://` protocol are read-only tables.

The URI includes the host name, port, and path to the file. Each file must reside on a segment host in a location accessible by the WarehousePG superuser (`gpadmin`). The host name used in the URI must match a segment host name registered in the `gp_segment_configuration` system catalog table.

The `LOCATION` clause can have multiple URIs, as shown in this example:

```
CREATE EXTERNAL TABLE ext_expenses (
   name text, date date, amount float4, category text, desc1 text )
LOCATION ('file://host1:5432/data/expense/*.csv',
          'file://host2:5432/data/expense/*.csv',
          'file://host3:5432/data/expense/*.csv')
FORMAT 'CSV' (HEADER);
```

The number of URIs you specify in the `LOCATION` clause is the number of segment instances that will work in parallel to access the external table. For each URI, WarehousePG assigns a primary segment on the specified host to the file. For maximum parallelism when loading data, divide the data into as many equally sized files as you have primary segments. This ensures that all segments participate in the load. The number of external files per segment host cannot exceed the number of primary segment instances on that host. For example, if your array has four primary segment instances per segment host, you can place four external files on each segment host. Tables based on the `file://` protocol can only be readable tables.

The system view `pg_max_external_files` shows how many external table files are permitted per external table. This view lists the available file slots per segment host when using the `file:// protocol` . The view is only applicable for the `file:// protocol` . For example:

```
SELECT * FROM pg_max_external_files;
```

Parent topic: Defining External Tables

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4.8.2.4 gpfdist:// Protocol

The `gpfdist://` protocol is used in a URI to reference a running `gpfdist` instance.

The gpfdist utility serves external data files from a directory on a file host to all WarehousePG segments in parallel.

`gpfdist` is located in the `$GPHOME/bin` directory on your WarehousePG coordinator host and on each segment host.

Run `gpfdist` on the host where the external data files reside. For readable external tables, `gpfdist` uncompresses `gzip` (`.gz`) and `bzip2` (`.bz2`) files automatically. For writable external tables, data is compressed using `gzip` if the target file has a `.gz` extension. You can use the wildcard character (*) or other C-style pattern matching to denote multiple files to read. The files specified are assumed to be relative to the directory that you specified when you started the `gpfdist` instance.

> **Note** Compression is not supported for readable and writeable external tables when the `gpfdist` utility runs on Windows platforms.

All primary segments access the external file(s) in parallel, subject to the number of segments set in the `gp_external_max_segments` server configuration parameter. Use multiple `gpfdist` data sources in a `CREATE EXTERNAL TABLE` statement to scale the external table's scan performance.

`gpfdist` supports data transformations. You can write a transformation process to convert external data from or to a format that is not directly supported with WarehousePG external tables.

For more information about configuring `gpfdist`, see Using the WarehousePG Parallel File Server (gpfdist).

See the `gpfdist` reference documentation for more information about using `gpfdist` with external tables.

Parent topic: Defining External Tables

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4.8.2.5 gpfdists:// Protocol

The `gpfdists://` protocol is a secure version of the `gpfdist:// protocol`.

To use it, you run the gpfdist utility with the `--ssl` option. When specified in a URI, the `gpfdists://` protocol enables encrypted communication and secure identification of the file server and the WarehousePG to protect against attacks such as eavesdropping and man-in-the-middle attacks.

`gpfdists` implements SSL security in a client/server scheme with the following attributes and limitations:

- Client certificates are required.
- Multilingual certificates are not supported.
- A Certificate Revocation List (CRL) is not supported.
- The `TLSv1` protocol is used with the `TLS_RSA_WITH_AES_128_CBC_SHA` encryption algorithm.
- SSL parameters cannot be changed.
- SSL renegotiation is supported.
- The SSL ignore host mismatch parameter is set to `false`.
- Private keys containing a passphrase are not supported for the `gpfdist` file server (`server.key`) and for the WarehousePG (`client.key`).
- Issuing certificates that are appropriate for the operating system in use is the user's responsibility. Generally, converting certificates as shown inhttps://www.sslshopper.com/ssl-converter.html is supported.

  > **Note** A server started with the `gpfdist --ssl` option can only communicate with the `gpfdists` protocol. A server that was started with `gpfdist` without the `--ssl` option can only communicate with the `gpfdist` protocol.

- The client certificate file, `client.crt`
- The client private key file, `client.key`

Use one of the following methods to invoke the `gpfdists` protocol.

- Run `gpfdist` with the `--ssl` option and then use the `gpfdists` protocol in the `LOCATION` clause of a `CREATE EXTERNAL TABLE` statement.
- Use a `gpload` YAML control file with the `SSL` option set to true. Running `gpload` starts the `gpfdist` server with the `--ssl` option, then uses the `gpfdists` protocol.

About the Required Certificate Files

The settings of the verify_gpfdists_cert server configuration parameter (default value `true`) and the gpfdist `--ssl_verify_peer <boolean>` option (default value `on`) control whether SSL certificate authentication is enabled when WarehousePG communicates with the `gpfdist` utility to either read data from or write data to an external data source. These settings also determine which of the following certificate files must reside in the `$PGDATA/gpfdists` directory on each WarehousePG segment:

- The client certificate file, `client.crt`
- The client private key file, `client.key`
- The trusted certificate authorities, `root.crt`

The certificate files required for each `verify_gpfdists_cert` and `--ssl_verify_peer` setting combination are identified in the table below:

verify_gpfdists_cert	--ssl_verify_peer	Required Certificate Files

on	on	`client.key`
		`client.crt`
		`root.crt`

on	off	`root.crt`
off	on	`client.key` `client.crt`
off	off	N/A

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4.8.2.6 pxf:// Protocol

You can use the WarehousePG Platform Extension Framework (PXF) `pxf://` protocol to access data residing in object store systems (Azure, Google Cloud Storage, Minio, S3), external Hadoop systems (HDFS, Hive, HBase), and SQL databases.

The PXF `pxf` protocol is packaged as a WarehousePG extension. The `pxf` protocol supports reading from external data stores. You can also write text, binary, and parquet-format data with the `pxf` protocol.

When you use the `pxf` protocol to query an external data store, you specify the directory, file, or table that you want to access. PXF requests the data from the data store and delivers the relevant portions in parallel to each WarehousePG segment instance serving the query.

You must explicitly initialize and start PXF before you can use the `pxf` protocol to read or write external data. You must also enable PXF in each database in which you want to allow users to create external tables to access external data, and grant permissions on the `pxf` protocol to those WarehousePG users.

For detailed information about configuring and using PXF and the `pxf` protocol, refer to Accessing External Data with PXF.

Parent topic: Defining External Tables

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4.8.2.7 s3:// Protocol

The `s3` protocol is used in a URL that specifies the location of an Amazon S3 bucket and a prefix to use for reading or writing files in the bucket.

Amazon Simple Storage Service (Amazon S3) provides secure, durable, highly-scalable object storage. For information about Amazon S3, see Amazon S3.

You can define read-only external tables that use existing data files in the S3 bucket for table data, or writable external tables that store the data from INSERT operations to files in the S3 bucket. WarehousePG uses the S3 URL and prefix specified in the protocol URL either to select one or more files for a read-only table, or to define the location and filename format to use when uploading S3 files for `INSERT` operations to writable tables.

The `s3` protocol also supports Dell Elastic Cloud Storage (ECS), an Amazon S3 compatible service.

> **Note** The `pxf` protocol can access data in S3 and other object store systems such as Azure, Google Cloud Storage, and Minio. The `pxf` protocol can also access data in external Hadoop systems (HDFS, Hive, HBase), and SQL databases. See pxf:// Protocol.

This topic contains the sections:

- Configuring the s3 Protocol
- Using s3 External Tables
- About the s3 Protocol LOCATION URL
- About Reading and Writing S3 Data Files
- s3 Protocol AWS Server-Side Encryption Support
- s3 Protocol Proxy Support
- About Providing the S3 Authentication Credentials
- About the s3 Protocol Configuration File
- About Specifying the Configuration File Location
- s3 Protocol Limitations
- Using the gpcheckcloud Utility

Configuring the s3 Protocol

You must configure the `s3` protocol before you can use it. Perform these steps in each database in which you want to use the protocol:

1. Create the read and write functions for the `s3` protocol library:

   ```
   CREATE OR REPLACE FUNCTION write_to_s3() RETURNS integer AS
      '$libdir/gps3ext.so', 's3_export' LANGUAGE C STABLE;
   ```

   ```
   CREATE OR REPLACE FUNCTION read_from_s3() RETURNS integer AS
      '$libdir/gps3ext.so', 's3_import' LANGUAGE C STABLE;
   ```

2. Declare the `s3` protocol and specify the read and write functions you created in the previous step:

   To allow only WarehousePG superusers to use the protocol, create it as follows:

   ```
   CREATE PROTOCOL s3 (writefunc = write_to_s3, readfunc = read_from_s3);
   ```

   If you want to permit non-superusers to use the `s3` protocol, create it as a `TRUSTED` protocol and `GRANT` access to those users. For example:

   ```
   CREATE TRUSTED PROTOCOL s3 (writefunc = write_to_s3, readfunc = read_from_s3);
   GRANT ALL ON PROTOCOL s3 TO user1, user2;
   ```

   > **Note** The protocol name `s3` must be the same as the protocol of the URL specified for the external table that you create to access an S3 resource.

   The corresponding function is called by every WarehousePG segment instance.

Using s3 External Tables

Follow these basic steps to use the `s3` protocol with WarehousePG external tables. Each step includes links to relevant topics from which you can obtain more information. See also s3 Protocol Limitations to better understand the capabilities and limitations of s3 external tables:

1. Configure the s3 Protocol.
2. Create the `s3` protocol configuration file:
   1. Create a template `s3` protocol configuration file using the `gpcheckcloud` utility:

      ```
      gpcheckcloud -t > ./mytest_s3.config
      ```

   2. (Optional) Edit the template file to specify the `accessid` and `secret` authentication credentials required to connect to the S3 location. See About Providing the S3 Authentication Credentials and About the s3 Protocol Configuration File for information about specifying these and other `s3` protocol configuration parameters.
3. WarehousePG can access an `s3` protocol configuration file when the file is located on each segment host or when the file is served up by an `http/https` server. Identify where you plan to locate the configuration file, and note the location and configuration option (if applicable). Refer to About Specifying the Configuration File Location for more information about the location options for the file.

   If you are relying on the AWS credential file to authenticate, this file must reside at `~/.aws/credentials` on each WarehousePG segment host.

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4. Use the `gpcheckcloud` utility to validate connectivity to the S3 bucket. You must specify the S3 endpoint name and bucket that you want to check.

   For example, if the `s3` protocol configuration file resides in the default location, you would run the following command:

   ```
   gpcheckcloud -c "s3://<s3-endpoint>/<s3-bucket>"
   ```

   `gpcheckcloud` attempts to connect to the S3 endpoint and lists any files in the S3 bucket, if available. A successful connection ends with the message:

   ```
   Your configuration works well.
   ```

   You can optionally use `gpcheckcloud` to validate uploading to and downloading from the S3 bucket. Refer to Using the gpcheckcloud Utility for information about this utility and other usage examples.

5. Create an s3 external table by specifying an `s3` protocol URL in the `CREATE EXTERNAL TABLE` command, `LOCATION` clause.

   For read-only s3 tables, the URL defines the location and prefix used to select existing data files that comprise the s3 table. For example:

   ```
   CREATE READABLE EXTERNAL TABLE S3TBL (date text, time text, amt int)
      LOCATION('s3://s3-us-west-2.amazonaws.com/s3test.example.com/dataset1/normal/ config=/home/gpadmin/aws_s3/s3.conf')
      FORMAT 'csv';
   ```

   For writable s3 tables, the protocol URL defines the S3 location in which WarehousePG writes the data files that back the table for `INSERT` operations. You can also specify a prefix that WarehousePG will add to the files that it creates. For example:

   ```
   CREATE WRITABLE EXTERNAL TABLE S3WRIT (LIKE S3TBL)
      LOCATION('s3://s3-us-west-2.amazonaws.com/s3test.example.com/dataset1/normal/ config=/home/gpadmin/aws_s3/s3.conf')
      FORMAT 'csv';
   ```

   Refer to About the s3 Protocol LOCATION URL for more information about the `s3` protocol URL.

About the s3 Protocol LOCATION URL

When you use the `s3` protocol, you specify an S3 file location and optional configuration file location and region parameters in the `LOCATION` clause of the `CREATE EXTERNAL TABLE` command. The syntax follows:

```
's3://<S3_endpoint>[:<port>]/<bucket_name>/[<S3_prefix>] [region=<S3_region>] [config=<config_file_location> | config_server=<url>] [section=<section_name>]'
```

The `s3` protocol requires that you specify the S3 endpoint and S3 bucket name. Each WarehousePG segment host must have access to the S3 location. The optional S3_prefix value is used to select files for read-only S3 tables, or as a filename prefix to use when uploading files for s3 writable tables.

> **Note** The WarehousePG `s3` protocol URL must include the S3 endpoint hostname.

To specify an ECS endpoint (an Amazon S3 compatible service) in the `LOCATION` clause, you must set the `s3` protocol configuration file parameter `version` to `2`. The `version` parameter controls whether the `region` parameter is used in the `LOCATION` clause. You can also specify an Amazon S3 location when the `version` parameter is 2. For information about the `version` parameter, see About the s3 Protocol Configuration File.

> **Note** Although the S3_prefix is an optional part of the syntax, you should always include an S3 prefix for both writable and read-only s3 tables to separate datasets as part of the CREATE EXTERNAL TABLE syntax.

For writable s3 tables, the `s3` protocol URL specifies the endpoint and bucket name where WarehousePG uploads data files for the table. The S3 file prefix is used for each new file uploaded to the S3 location as a result of inserting data to the table. See About Reading and Writing S3 Data Files.

For read-only s3 tables, the S3 file prefix is optional. If you specify an S3_prefix, then the `s3` protocol selects all files that start with the specified prefix as data files for the external table. The `s3` protocol does not use the slash character (`/`) as a delimiter, so a slash character following a prefix is treated as part of the prefix itself.

For example, consider the following 5 files that each have the S3_endpoint named `s3-us-west-2.amazonaws.com` and the bucket_name `test1`:

```
s3://s3-us-west-2.amazonaws.com/test1/abc
s3://s3-us-west-2.amazonaws.com/test1/abc/
s3://s3-us-west-2.amazonaws.com/test1/abc/xx
s3://s3-us-west-2.amazonaws.com/test1/abcdef
s3://s3-us-west-2.amazonaws.com/test1/abcdefff
```

- If the S3 URL is provided as `s3://s3-us-west-2.amazonaws.com/test1/abc`, then the `abc` prefix selects all 5 files.
- If the S3 URL is provided as `s3://s3-us-west-2.amazonaws.com/test1/abc/`, then the `abc/` prefix selects the files `s3://s3-us-west-2.amazonaws.com/test1/abc/` and `s3://s3-us-west-2.amazonaws.com/test1/abc/xx`.
- If the S3 URL is provided as `s3://s3-us-west-2.amazonaws.com/test1/abcd`, then the `abcd` prefix selects the files `s3://s3-us-west-2.amazonaws.com/test1/abcdef` and `s3://s3-us-west-2.amazonaws.com/test1/abcdefff`

Wildcard characters are not supported in an S3_prefix; however, the S3 prefix functions as if a wildcard character immediately followed the prefix itself.

All of the files selected by the S3 URL (S3_endpoint/bucket_name/S3_prefix) are used as the source for the external table, so they must have the same format. Each file must also contain complete data rows. A data row cannot be split between files.

For information about the Amazon S3 endpoints see http://docs.aws.amazon.com/general/latest/gr/rande.html#s3_region. For information about S3 buckets and folders, see the Amazon S3 documentation https://aws.amazon.com/documentation/s3/. For information about the S3 file prefix, see the Amazon S3 documentation Listing Keys Hierarchically Using a Prefix and Delimiter.

You use the `config` or `config_server` parameter to specify the location of the required `s3` protocol configuration file that contains AWS connection credentials and communication parameters as described in About Specifying the Configuration File Location.

Use the `section` parameter to specify the name of the configuration file section from which the `s3` protocol reads configuration parameters. The default `section` is named `default`. When you specify the section name in the configuration file, enclose it in brackets (for example, `[default]`).

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About Reading and Writing S3 Data Files

You can use the `s3` protocol to read and write data files on Amazon S3.

Reading S3 Files

The S3 permissions on any file that you read must include `Open/Download` and `View` for the S3 user ID that accesses the files.

For read-only s3 tables, all of the files specified by the S3 file location (S3_endpoint/bucket_name/S3_prefix) are used as the source for the external table and must have the same format. Each file must also contain complete data rows. If the files contain an optional header row, the column names in the header row cannot contain a newline character (`\n`) or a carriage return (`\r`). Also, the column delimiter cannot be a newline character (`\n`) or a carriage return character (`\r`).

The `s3` protocol recognizes gzip and deflate compressed files and automatically decompresses the files. For gzip compression, the protocol recognizes the format of a gzip compressed file. For deflate compression, the protocol assumes a file with the `.deflate` suffix is a deflate compressed file.

Each WarehousePG segment can download one file at a time from the S3 location using several threads. To take advantage of the parallel processing performed by the WarehousePG segments, the files in the S3 location should be similar in size and the number of files should allow for multiple segments to download the data from the S3 location. For example, if the WarehousePG cluster consists of 16 segments and there was sufficient network bandwidth, creating 16 files in the S3 location allows each segment to download a file from the S3 location. In contrast, if the location contained only 1 or 2 files, only 1 or 2 segments download data.

Writing S3 Files

Writing a file to S3 requires that the S3 user ID have `Upload/Delete` permissions.

When you initiate an `INSERT` operation on a writable s3 table, each WarehousePG segment uploads a single file to the configured S3 bucket using the filename format `<prefix><segment_id><random>.<extension>[.gz]` where:

- `<prefix>` is the prefix specified in the S3 URL.
- `<segment_id>` is the WarehousePG segment ID.
- `<random>` is a random number that is used to ensure that the filename is unique.
- `<extension>` describes the file type (`.txt` or .csv, depending on the value you provide in the `FORMAT` clause of `CREATE WRITABLE EXTERNAL TABLE`). Files created by the `gpcheckcloud` utility always uses the extension .data.
- .gz is appended to the filename if compression is enabled for s3 writable tables (the default).

You can configure the buffer size and the number of threads that segments use for uploading files. See About the s3 Protocol Configuration File.

s3 Protocol AWS Server-Side Encryption Support

WarehousePG supports server-side encryption using Amazon S3-managed keys (SSE-S3) for AWS S3 files you access with readable and writable external tables created using the `s3` protocol. SSE-S3 encrypts your object data as it writes to disk, and transparently decrypts the data for you when you access it.

> **Note** The `s3` protocol supports SSE-S3 only for Amazon Web Services S3 files. SS3-SE is not supported when accessing files in S3 compatible services.

Your S3 account permissions govern your access to all S3 bucket objects, whether the data is encrypted or not. However, you must configure your client to use S3-managed keys for accessing encrypted data.

Refer to Protecting Data Using Server-Side Encryption in the AWS documentation for additional information about AWS Server-Side Encryption.

Configuring S3 Server-Side Encryption

`s3` protocol server-side encryption is deactivated by default. To take advantage of server-side encryption on AWS S3 objects you write using the WarehousePG `s3` protocol, you must set the `server_side_encryption` configuration parameter in your `s3` protocol configuration file to the value `sse-s3` :

```
server_side_encryption = sse-s3
```

When the configuration file you provide to a `CREATE WRITABLE EXTERNAL TABLE` call using the `s3` protocol includes the `server_side_encryption = sse-s3` setting, WarehousePG applies encryption headers for you on all `INSERT` operations on that external table. S3 then encrypts on write the object(s) identified by the URI you provided in the `LOCATION` clause.

S3 transparently decrypts data during read operations of encrypted files accessed via readable external tables you create using the `s3` protocol. No additional configuration is required.

For further encryption configuration granularity, you may consider creating Amazon Web Services S3 *Bucket Policy*(s), identifying the objects you want to encrypt and the write actions on those objects as described in the Protecting Data Using Server-Side Encryption with Amazon S3-Managed Encryption Keys (SSE-S3) AWS documentation.

s3 Protocol Proxy Support

You can specify a URL that is the proxy that S3 uses to connect to a data source. S3 supports these protocols: HTTP and HTTPS. You can specify a proxy with the `s3` protocol configuration parameter `proxy` or an environment variable. If the configuration parameter is set, the environment variables are ignored.

To specify proxy with an environment variable, you set the environment variable based on the protocol: `http_proxy` or `https_proxy` . You can specify a different URL for each protocol by setting the appropriate environment variable. S3 supports these environment variables.

- `all_proxy` specifies the proxy URL that is used if an environment variable for a specific protocol is not set.
- `no_proxy` specifies a comma-separated list of hosts names that do not use the proxy specified by an environment variable.

The environment variables must be set must and must be accessible to WarehousePG on all WarehousePG hosts.

For information about the configuration parameter `proxy` , see About the s3 Protocol Configuration File.

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About Providing the S3 Authentication Credentials

The `s3` protocol obtains the S3 authentication credentials as follows:

- You specify the S3 `accessid` and `secret` parameters and their values in a named `section` of an s3 protocol configuration file. The default section from which the `s3` protocol obtains this information is named `[default]`.
- If you do not specify the `accessid` and `secret`, or these parameter values are empty, the `s3` protocol attempts to obtain the S3 authentication credentials from the `aws_access_key_id` and `aws_secret_access_key` parameters specified in a named `section` of the user's AWS credential file. The default location of this file is `~/.aws/credentials`, and the default section is named `[default]`.

About the s3 Protocol Configuration File

An `s3` protocol configuration file contains Amazon Web Services (AWS) connection credentials and communication parameters.

The `s3` protocol configuration file is a text file that contains named sections and parameters. The default section is named `[default]`. An example configuration file follows:

```
[default]
secret = "secret"
accessid = "user access id"
threadnum = 3
chunksize = 67108864
```

You can use the WarehousePG `gpcheckcloud` utility to test the s3 protocol configuration file. See Using the gpcheckcloud Utility.

s3 Configuration File Parameters

`accessid` Optional. AWS S3 ID to access the S3 bucket. Refer to About Providing the S3 Authentication Credentials for more information about specifying authentication credentials.

`secret` Optional. AWS S3 passcode for the S3 ID to access the S3 bucket. Refer to About Providing the S3 Authentication Credentials for more information about specifying authentication credentials.

`autocompress` For writable s3 external tables, this parameter specifies whether to compress files (using gzip) before uploading to S3. Files are compressed by default if you do not specify this parameter.

`chunksize` The buffer size that each segment thread uses for reading from or writing to the S3 server. The default is 64 MB. The minimum is 8MB and the maximum is 128MB.

When inserting data to a writable s3 table, each WarehousePG segment writes the data into its buffer (using multiple threads up to the `threadnum` value) until it is full, after which it writes the buffer to a file in the S3 bucket. This process is then repeated as necessary on each segment until the insert operation completes.

Because Amazon S3 allows a maximum of 10,000 parts for multipart uploads, the minimum `chunksize` value of 8MB supports a maximum insert size of 80GB per WarehousePG segment. The maximum `chunksize` value of 128MB supports a maximum insert size 1.28TB per segment. For writable s3 tables, you must ensure that the `chunksize` setting can support the anticipated table size of your table. See Multipart Upload Overview in the S3 documentation for more information about uploads to S3.

`encryption` Use connections that are secured with Secure Sockets Layer (SSL). Default value is `true`. The values `true`, `t`, `on`, `yes`, and `y` (case insensitive) are treated as `true`. Any other value is treated as `false`.

If the port is not specified in the URL in the `LOCATION` clause of the `CREATE EXTERNAL TABLE` command, the configuration file `encryption` parameter affects the port used by the `s3` protocol (port 80 for HTTP or port 443 for HTTPS). If the port is specified, that port is used regardless of the encryption setting.

`gpcheckcloud_newline` When downloading files from an S3 location, the `gpcheckcloud` utility appends a new line character to last line of a file if the last line of a file does not have an EOL (end of line) character. The default character is `\n` (newline). The value can be `\n`, `\r` (carriage return), or `\n\r` (newline/carriage return).

Adding an EOL character prevents the last line of one file from being concatenated with the first line of next file.

`low_speed_limit` The upload/download speed lower limit, in bytes per second. The default speed is 10240 (10K). If the upload or download speed is slower than the limit for longer than the time specified by `low_speed_time`, then the connection is stopped and retried. After 3 retries, the `s3` protocol returns an error. A value of 0 specifies no lower limit.

`low_speed_time` When the connection speed is less than `low_speed_limit`, this parameter specified the amount of time, in seconds, to wait before cancelling an upload to or a download from the S3 bucket. The default is 60 seconds. A value of 0 specifies no time limit.

`proxy` Specify a URL that is the proxy that S3 uses to connect to a data source. S3 supports these protocols: HTTP and HTTPS. This is the format for the parameter.

```
proxy = <protocol>://[<user>:<password>@]<proxyhost>[:<port>]
```

If this parameter is not set or is an empty string (`proxy = ""`), S3 uses the proxy specified by the environment variable `http_proxy` or `https_proxy` (and the environment variables `all_proxy` and `no_proxy`). The environment variable that S3 uses depends on the protocol. For information about the environment variables, see s3 Protocol Proxy Support.

There can be at most one `proxy` parameter in the configuration file. The URL specified by the parameter is the proxy for all supported protocols.

`server_side_encryption` The S3 server-side encryption method that has been configured for the bucket. WarehousePG supports only server-side encryption with Amazon S3-managed keys, identified by the configuration parameter value `sse-s3`. Server-side encryption is deactivated (`none`) by default.

`threadnum` The maximum number of concurrent threads a segment can create when uploading data to or downloading data from the S3 bucket. The default is 4. The minimum is 1 and the maximum is 8.

`verifycert` Controls how the `s3` protocol handles authentication when establishing encrypted communication between a client and an S3 data source over HTTPS. The value is either `true` or `false`. The default value is `true`.

- `verifycert=false` - Ignores authentication errors and allows encrypted communication over HTTPS.
- `verifycert=true` - Requires valid authentication (a proper certificate) for encrypted communication over HTTPS.

Setting the value to `false` can be useful in testing and development environments to allow communication without changing certificates.

> **Caution** Setting the value to `false` exposes a security risk by ignoring invalid credentials when establishing communication between a client and a S3 data store.

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`version` Specifies the version of the information specified in the `LOCATION` clause of the `CREATE EXTERNAL TABLE` command. The value is either `1` or `2`. The default value is `1`.

If the value is `1`, the `LOCATION` clause supports an Amazon S3 URL, and does not contain the `region` parameter. If the value is `2`, the `LOCATION` clause supports S3 compatible services and must include the `region` parameter. The `region` parameter specifies the S3 data source region. For this S3 URL `s3://s3-us-west-2.amazonaws.com/s3test.example.com/dataset1/normal/`, the AWS S3 region is `us-west-2`.

If `version` is 1 or is not specified, this is an example of the `LOCATION` clause of the `CREATE EXTERNAL TABLE` command that specifies an Amazon S3 endpoint.

```
LOCATION ('s3://s3-us-west-2.amazonaws.com/s3test.example.com/dataset1/normal/ config=/home/gpadmin/aws_s3/s3.conf')
```

If `version` is 2, this is an example `LOCATION` clause with the `region` parameter for an AWS S3 compatible service.

```
LOCATION ('s3://test.company.com/s3test.company/test1/normal/ region=local-test config=/home/gpadmin/aws_s3/s3.conf')
```

If `version` is 2, the `LOCATION` clause can also specify an Amazon S3 endpoint. This example specifies an Amazon S3 endpoint that uses the `region` parameter.

```
LOCATION ('s3://s3-us-west-2.amazonaws.com/s3test.example.com/dataset1/normal/ region=us-west-2 config=/home/gpadmin/aws_s3/s3.conf')
```

> **Note** WarehousePG can require up to `threadnum * chunksize` memory on each segment host when uploading or downloading S3 files. Consider this `s3` protocol memory requirement when you configure overall WarehousePG memory.

About Specifying the Configuration File Location

The default location of the `s3` protocol configuration file is a file named `s3.conf` that resides in the data directory of each WarehousePG segment instance:

```
<gpseg_data_dir>/<gpseg_prefix><N>/s3/s3.conf
```

The gpseg_data_dir is the path to the WarehousePG segment data directory, the gpseg_prefix is the segment prefix, and N is the segment ID. The segment data directory, prefix, and ID are set when you initialize a WarehousePG cluster.

You may choose an alternate location for the `s3` protocol configuration file by specifying the optional `config` or `config_server` parameters in the `LOCATION` URL:

- You can simplify the configuration by using a single configuration file that resides in the same file system location on each segment host. In this scenario, you specify the `config` parameter in the `LOCATION` clause to identify the absolute path to the file. The following example specifies a location in the `gpadmin` home directory:

  ```
  LOCATION ('s3://s3-us-west-2.amazonaws.com/test/my_data config=/home/gpadmin/s3.conf')
  ```

  The `/home/gpadmin/s3.conf` file must reside on each segment host, and all segment instances on a host use the file.

- You also have the option to use an `http/https` server to serve up the configuration file. In this scenario, you specify an `http/https` server URL in the `config_server` parameter. You are responsible for configuring and starting the server, and each WarehousePG segment host must be able to access the server. The following example specifies an IP address and port for an `https` server:

  ```
  LOCATION ('s3://s3-us-west-2.amazonaws.com/test/my_data config_server=https://203.0.113.0:8553')
  ```

s3 Protocol Limitations

These are `s3` protocol limitations:

- Only the S3 path-style URL is supported.

  ```
  s3://<S3_endpoint>/<bucketname>/[<S3_prefix>]
  ```

- Only the S3 endpoint is supported. The protocol does not support virtual hosting of S3 buckets (binding a domain name to an S3 bucket).

- AWS signature version 4 signing process is supported.

  For information about the S3 endpoints supported by each signing process, see http://docs.aws.amazon.com/general/latest/gr/rande.html#s3_region.

- Only a single URL and optional configuration file location and region parameters is supported in the `LOCATION` clause of the `CREATE EXTERNAL TABLE` command.

- If the `NEWLINE` parameter is not specified in the `CREATE EXTERNAL TABLE` command, the newline character must be identical in all data files for specific prefix. If the newline character is different in some data files with the same prefix, read operations on the files might fail.

- For writable s3 external tables, only the `INSERT` operation is supported. `UPDATE`, `DELETE`, and `TRUNCATE` operations are not supported.

- Because Amazon S3 allows a maximum of 10,000 parts for multipart uploads, the maximum `chunksize` value of 128MB supports a maximum insert size of 1.28TB per WarehousePG segment for writable s3 tables. You must ensure that the `chunksize` setting can support the anticipated table size of your table. See Multipart Upload Overview in the S3 documentation for more information about uploads to S3.

- To take advantage of the parallel processing performed by the WarehousePG segment instances, the files in the S3 location for read-only s3 tables should be similar in size and the number of files should allow for multiple segments to download the data from the S3 location. For example, if the WarehousePG cluster consists of 16 segments and there was sufficient network bandwidth, creating 16 files in the S3 location allows each segment to download a file from the S3 location. In contrast, if the location contained only 1 or 2 files, only 1 or 2 segments download data.

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Using the gpcheckcloud Utility

The WarehousePG utility `gpcheckcloud` helps users create an `s3` protocol configuration file and test a configuration file. You can specify options to test the ability to access an S3 bucket with a configuration file, and optionally upload data to or download data from files in the bucket.

If you run the utility without any options, it sends a template configuration file to `STDOUT`. You can capture the output and create an `s3` configuration file to connect to Amazon S3.

The utility is installed in the WarehousePG `$GPHOME/bin` directory.

Syntax

```
gpcheckcloud {-c | -d} "s3://<S3_endpoint>/<bucketname>/[<S3_prefix>] [config=<path_to_config_file>]"

gpcheckcloud -u <file_to_upload> "s3://<S3_endpoint>/<bucketname>/[<S3_prefix>] [config=<path_to_config_file>]"
gpcheckcloud -t

gpcheckcloud -h
```

Options

`-c` Connect to the specified S3 location with the configuration specified in the `s3` protocol URL and return information about the files in the S3 location.

If the connection fails, the utility displays information about failures such as invalid credentials, prefix, or server address (DNS error), or server not available.

`-d` Download data from the specified S3 location with the configuration specified in the `s3` protocol URL and send the output to `STDOUT`.

If files are gzip compressed or have a `.deflate` suffix to indicate deflate compression, the uncompressed data is sent to `STDOUT`.

`-u` Upload a file to the S3 bucket specified in the `s3` protocol URL using the specified configuration file if available. Use this option to test compression and `chunksize` and `autocompress` settings for your configuration.

`-t` Sends a template configuration file to `STDOUT`. You can capture the output and create an `s3` configuration file to connect to Amazon S3.

`-h` Display `gpcheckcloud` help.

Examples

This example runs the utility without options to create a template `s3` configuration file `mytest_s3.config` in the current directory.

```
gpcheckcloud -t > ./mytest_s3.config
```

This example attempts to upload a local file, test-data.csv to an S3 bucket location using the `s3` configuration file `s3.mytestconf`:

```
gpcheckcloud -u ./test-data.csv "s3://s3-us-west-2.amazonaws.com/test1/abc config=s3.mytestconf"
```

A successful upload results in one or more files placed in the S3 bucket using the filename format `abc<segment_id><random>.data[.gz]`. See About Reading and Writing S3 Data Files.

This example attempts to connect to an S3 bucket location with the `s3` protocol configuration file `s3.mytestconf`.

```
gpcheckcloud -c "s3://s3-us-west-2.amazonaws.com/test1/abc config=s3.mytestconf"
```

This example attempts to connect to an S3 bucket location using the default location for the `s3` protocol configuration file (`s3/s3.conf` in segment data directories):

```
gpcheckcloud -c "s3://s3-us-west-2.amazonaws.com/test1/abc"
```

Download all files from the S3 bucket location and send the output to `STDOUT`.

```
gpcheckcloud -d "s3://s3-us-west-2.amazonaws.com/test1/abc config=s3.mytestconf"
```

Parent topic: Defining External Tables

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4.8.2.8 Creating a Custom Protocol

A custom protocol allows you to connect WarehousePG to a data source that cannot be accessed with the `file://`, `gpfdist://`, or `pxf://` protocols.

Creating a custom protocol requires that you implement a set of C functions with specified interfaces, declare the functions in WarehousePG, and then use the `CREATE TRUSTED PROTOCOL` command to enable the protocol in the database.

See Example Custom Data Access Protocol for an example.

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4.8.2.9 Handling Errors in External Table Data

By default, if external table data contains an error, the command fails and no data loads into the target database table.

Define the external table with single row error handling to enable loading correctly formatted rows and to isolate data errors in external table data. See Handling Load Errors.

The `gpfdist` file server uses the `HTTP` protocol. External table queries that use `LIMIT` end the connection after retrieving the rows, causing an HTTP socket error. If you use `LIMIT` in queries of external tables that use the `gpfdist://` or `http:// protocols`, ignore these errors – data is returned to the database as expected.

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4.8.2.10 Creating and Using External Web Tables

External web tables allow WarehousePG to treat dynamic data sources like regular database tables. Because web table data can change as a query runs, the data is not rescannable.

`CREATE EXTERNAL WEB TABLE` creates a web table definition. You can define command-based or URL-based external web tables. The definition forms are distinct: you cannot mix command-based and URL-based definitions.

Parent topic: Defining External Tables

Command-based External Web Tables

The output of a shell command or script defines command-based web table data. Specify the command in the `EXECUTE` clause of `CREATE EXTERNAL WEB TABLE`. The data is current as of the time the command runs. The `EXECUTE` clause runs the shell command or script on the specified coordinator, and/or segment host or hosts. The command or script must reside on the hosts corresponding to the host(s) defined in the `EXECUTE` clause.

By default, the command is run on segment hosts when active segments have output rows to process. For example, if each segment host runs four primary segment instances that have output rows to process, the command runs four times per segment host. You can optionally limit the number of segment instances that run the web table command. All segments included in the web table definition in the `ON` clause run the command in parallel.

The command that you specify in the external table definition is run from the database and cannot access environment variables from `.bashrc` or `.profile`. Set environment variables in the `EXECUTE` clause. For example:

```
=# CREATE EXTERNAL WEB TABLE output (output text)
    EXECUTE 'PATH=/home/gpadmin/programs; export PATH; myprogram.sh'
    FORMAT 'TEXT';
```

Scripts must be executable by the `gpadmin` user and reside in the same location on the coordinator or segment hosts.

The following command defines a web table that runs a script. The script runs on each segment host where a segment has output rows to process.

```
=# CREATE EXTERNAL WEB TABLE log_output
    (linenum int, message text)
    EXECUTE '/var/load_scripts/get_log_data.sh' ON HOST
    FORMAT 'TEXT' (DELIMITER '|');
```

URL-based External Web Tables

A URL-based web table accesses data from a web server using the HTTP protocol. Web table data is dynamic; the data is not rescannable.

Specify the `LOCATION` of files on a web server using `http://`. The web data file(s) must reside on a web server that WarehousePG segment hosts can access. The number of URLs specified corresponds to the number of segment instances that work in parallel to access the web table. For example, if you specify two external files to a WarehousePG cluster with eight primary segments, two of the eight segments access the web table in parallel at query runtime.

The following sample command defines a web table that gets data from several URLs.

```
=# CREATE EXTERNAL WEB TABLE ext_expenses (name text,
  date date, amount float4, category text, description text)
  LOCATION (

  'http://intranet.company.com/expenses/sales/file.csv',
  'http://intranet.company.com/expenses/exec/file.csv',
  'http://intranet.company.com/expenses/finance/file.csv',
  'http://intranet.company.com/expenses/ops/file.csv',
  'http://intranet.company.com/expenses/marketing/file.csv',
  'http://intranet.company.com/expenses/eng/file.csv'

   )
  FORMAT 'CSV' ( HEADER );
```

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4.8.2.11 Examples for Creating External Tables

examples/index.md editTarget: originalFilePath

These examples show how to define external data with different protocols. Each `CREATE EXTERNAL TABLE` command can contain only one protocol.

> **Note** When using IPv6, always enclose the numeric IP addresses in square brackets.

Start gpfdist before you create external tables with the gpfdist protocol. The following code starts the gpfdist file server program in the background on port*8081* serving files from directory /var/data/staging. The logs are saved in /home/gpadmin/log.

```
gpfdist -p 8081 -d /var/data/staging -l /home/gpadmin/log &
```

- Example 1—Single gpfdist instance on single-NIC machine
- Example 2—Multiple gpfdist instances
- Example 3—Multiple gpfdists instances
- Example 4—Single gpfdist instance with error logging
- Example 5—TEXT Format on a Hadoop Distributed File Server
- Example 6—Multiple files in CSV format with header rows
- Example 7—Readable External Web Table with Script
- Example 8—Writable External Table with gpfdist
- Example 9—Writable External Web Table with Script
- Example 10—Readable and Writable External Tables with XML Transformations

Parent topic: Defining External Tables

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4.8.2.11.1 Example 1—Single gpfdist instance on single-NIC machine

examples/example-1-single-gpfdist-instance-on-single-nic-machine.md editTarget: originalFilePath

---

Creates a readable external table, `ext_expenses`, using the `gpfdist` protocol. The files are formatted with a pipe (|) as the column delimiter.

```
=# CREATE EXTERNAL TABLE ext_expenses ( name text,
    date date, amount float4, category text, desc1 text )
    LOCATION ('gpfdist://etlhost-1:8081/*')
FORMAT 'TEXT' (DELIMITER '|');
```

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4.8.2.11.2 Example 2—Multiple gpfdist instances

examples/example-2-multiple-gpfdist-instances.md editTarget: originalFilePath

---

Creates a readable external table, *ext_expenses,* using the gpfdist protocol from all files with the *txt* extension. The column delimiter is a pipe (|) and NULL (' ') is a space.

```
=# CREATE EXTERNAL TABLE ext_expenses ( name text,
   date date,  amount float4, category text, desc1 text )
   LOCATION ('gpfdist://etlhost-1:8081/*.txt',
             'gpfdist://etlhost-2:8081/*.txt')
   FORMAT 'TEXT' ( DELIMITER '|' NULL ' ') ;
```

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4.8.2.11.3 Example 3—Multiple gpfdists instances

examples/example-3-multiple-gpfdists-instances.md editTarget: originalFilePath

---

Creates a readable external table, *ext_expenses*, from all files with the *txt* extension using the `gpfdists` protocol. The column delimiter is a pipe (|) and NULL (' ') is a space. For information about the location of security certificates, see gpfdists:// Protocol.

1. Run `gpfdist` with the `--ssl` option.

2. Run the following command.

```
=# CREATE EXTERNAL TABLE ext_expenses ( name text,
   date date,  amount float4, category text, desc1 text )
   LOCATION ('gpfdists://etlhost-1:8081/*.txt',
             'gpfdists://etlhost-2:8082/*.txt')
   FORMAT 'TEXT' ( DELIMITER '|' NULL ' ') ;
```

Parent topic: Examples for Creating External Tables

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4.8.2.11.4 Example 4—Single gpfdist instance with error logging

examples/example-4-single-gpfdist-instance-with-error-logging.md editTarget: originalFilePath

---

Uses the gpfdist protocol to create a readable external table, `ext_expenses,` from all files with the *txt* extension. The column delimiter is a pipe (|) and NULL (' ') is a space.

Access to the external table is single row error isolation mode. Input data formatting errors are captured internally in WarehousePG with a description of the error. See Viewing Bad Rows in the Error Log for information about investigating error rows. You can view the errors, fix the issues, and then reload the rejected data. If the error count on a segment is greater than five (the `SEGMENT REJECT LIMIT` value), the entire external table operation fails and no rows are processed.

```
=# CREATE EXTERNAL TABLE ext_expenses ( name text,
   date date, amount float4, category text, desc1 text )
   LOCATION ('gpfdist://etlhost-1:8081/*.txt',
             'gpfdist://etlhost-2:8082/*.txt')
   FORMAT 'TEXT' ( DELIMITER '|' NULL ' ')
   LOG ERRORS SEGMENT REJECT LIMIT 5;
```

To create the readable ext_expenses table from CSV-formatted text files:

```
=# CREATE EXTERNAL TABLE ext_expenses ( name text,
   date date,  amount float4, category text, desc1 text )
   LOCATION ('gpfdist://etlhost-1:8081/*.txt',
             'gpfdist://etlhost-2:8082/*.txt')
   FORMAT 'CSV' ( DELIMITER ',' )
   LOG ERRORS SEGMENT REJECT LIMIT 5;
```

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4.8.2.11.5 Example 5—TEXT Format on a Hadoop Distributed File Server

examples/example-5-text-format-on-a-hadoop-distributed-file-server.md editTarget: originalFilePath

---

Creates a readable external table, *ext_expenses*, using the `pxf` protocol. The column delimiter is a pipe (|).

```
=# CREATE EXTERNAL TABLE ext_expenses ( name text,
   date date,  amount float4, category text, desc1 text )
   LOCATION ('pxf://dir/data/filename.txt?PROFILE=hdfs:text')
   FORMAT 'TEXT' (DELIMITER '|');
```

Refer to Accessing External Data with PXF for information about using the WarehousePG Platform Extension Framework (PXF) to access data on a Hadoop Distributed File System.

Parent topic: Examples for Creating External Tables

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4.8.2.11.6 Example 6—Multiple files in CSV format with header rows

examples/example-6-multiple-files-in-csv-format-with-header-rows.md editTarget: originalFilePath

---

Creates a readable external table, *ext_expenses*, using the `file` protocol. The files are `CSV` format and have a header row.

```
=# CREATE EXTERNAL TABLE ext_expenses ( name text,
   date date,  amount float4, category text, desc1 text )
   LOCATION ('file://filehost/data/international/*',
             'file://filehost/data/regional/*',
             'file://filehost/data/supplement/*.csv')
   FORMAT 'CSV' (HEADER);
```

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4.8.2.11.7 Example 7—Readable External Web Table with Script

examples/example-7-readable-web-external-table-with-script.md editTarget: originalFilePath

---

Creates a readable external web table that runs a script once per segment host:

```
=# CREATE EXTERNAL WEB TABLE log_output (linenum int,
    message text)
   EXECUTE '/var/load_scripts/get_log_data.sh' ON HOST
   FORMAT 'TEXT' (DELIMITER '|');
```

Parent topic: Examples for Creating External Tables

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4.8.2.11.8 Example 8—Writable External Table with gpfdist

examples/example-8-writable-external-table-with-gpfdist.md editTarget: originalFilePath

---

Creates a writable external table, *sales_out*, that uses gpfdist to write output data to the file *sales.out*. The column delimiter is a pipe (|) and NULL (' ') is a space. The file will be created in the directory specified when you started the gpfdist file server.

```
=# CREATE WRITABLE EXTERNAL TABLE sales_out (LIKE sales)
   LOCATION ('gpfdist://etl1:8081/sales.out')
   FORMAT 'TEXT' ( DELIMITER '|' NULL ' ')
   DISTRIBUTED BY (txn_id);
```

Parent topic: Examples for Creating External Tables

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4.8.2.11.9 Example 9—Writable External Web Table with Script

examples/example-9-writable-external-web-table-with-script.md editTarget: originalFilePath

---

Creates a writable external web table, `campaign_out`, that pipes output data received by the segments to an executable script, `to_adreport_etl.sh`:

```
=# CREATE WRITABLE EXTERNAL WEB TABLE campaign_out
    (LIKE campaign)
    EXECUTE '/var/unload_scripts/to_adreport_etl.sh'
    FORMAT 'TEXT' (DELIMITER '|');
```

Parent topic: Examples for Creating External Tables

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4.8.2.11.10 Example 10—Readable and Writable External Tables with XML Transformations

examples/example-10-readable-and-writable-external-tables-with-xml-transformations.md editTarget: originalFilePath

---

WarehousePG can read and write XML data to and from external tables with gpfdist. For information about setting up an XML transform, see Transforming External Data with gpfdist and gpload.

Parent topic: Examples for Creating External Tables

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4.8.3 Accessing External Data with PXF

Data managed by your organization may already reside in external sources such as Hadoop, object stores, and other SQL databases. The WarehousePG Platform Extension Framework (PXF) provides access to this external data via built-in connectors that map an external data source to a WarehousePG table definition.

PXF is installed with Hadoop and Object Storage connectors. These connectors enable you to read and write external data stored in text, Avro, JSON, RCFile, Parquet, SequenceFile, and ORC formats. You can use the JDBC connector to access an external SQL database.

The WarehousePG Platform Extension Framework includes a C-language extension and a Java service. After you configure and initialize PXF, you start a single PXF JVM process on each WarehousePG segment host. This long- running process concurrently serves multiple query requests.

For detailed information about the architecture of and using PXF, refer to the WarehousePG Platform Extension Framework PXF documentation

Parent topic: Working with External Data

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4.8.4 Using the WarehousePG Parallel File Server (gpfdist)

The gpfdist protocol is used in a `CREATE EXTERNAL TABLE` SQL command to access external data served by the WarehousePG `gpfdist` file server utility. When external data is served by gpfdist, all segments in the WarehousePG cluster can read or write external table data in parallel.

This topic describes the setup and management tasks for using gpfdist with external tables.

- About gpfdist and External Tables
- About gpfdist Setup and Performance
- Controlling Segment Parallelism
- Installing gpfdist
- Starting and Stopping gpfdist
- Troubleshooting gpfdist

Parent topic: Working with External Data

About gpfdist and External Tables

The `gpfdist` file server utility is located in the `$GPHOME/bin` directory on your WarehousePG coordinator host and on each segment host. When you start a `gpfdist` instance you specify a listen port and the path to a directory containing files to read or where files are to be written. For example, this command runs `gpfdist` in the background, listening on port 8801, and serving files in the `/home/gpadmin/external_files` directory:

```
$ gpfdist -p 8801 -d /home/gpadmin/external_files &
```

The `CREATE EXTERNAL TABLE` command `LOCATION` clause connects an external table definition to one or more `gpfdist` instances. If the external table is readable, the `gpfdist` server reads data records from files from in specified directory, packs them into a block, and sends the block in a response to a WarehousePG segment's request. The segments unpack rows they receive and distribute them according to the external table's distribution policy. If the external table is a writable table, segments send blocks of rows in a request to gpfdist and gpfdist writes them to the external file.

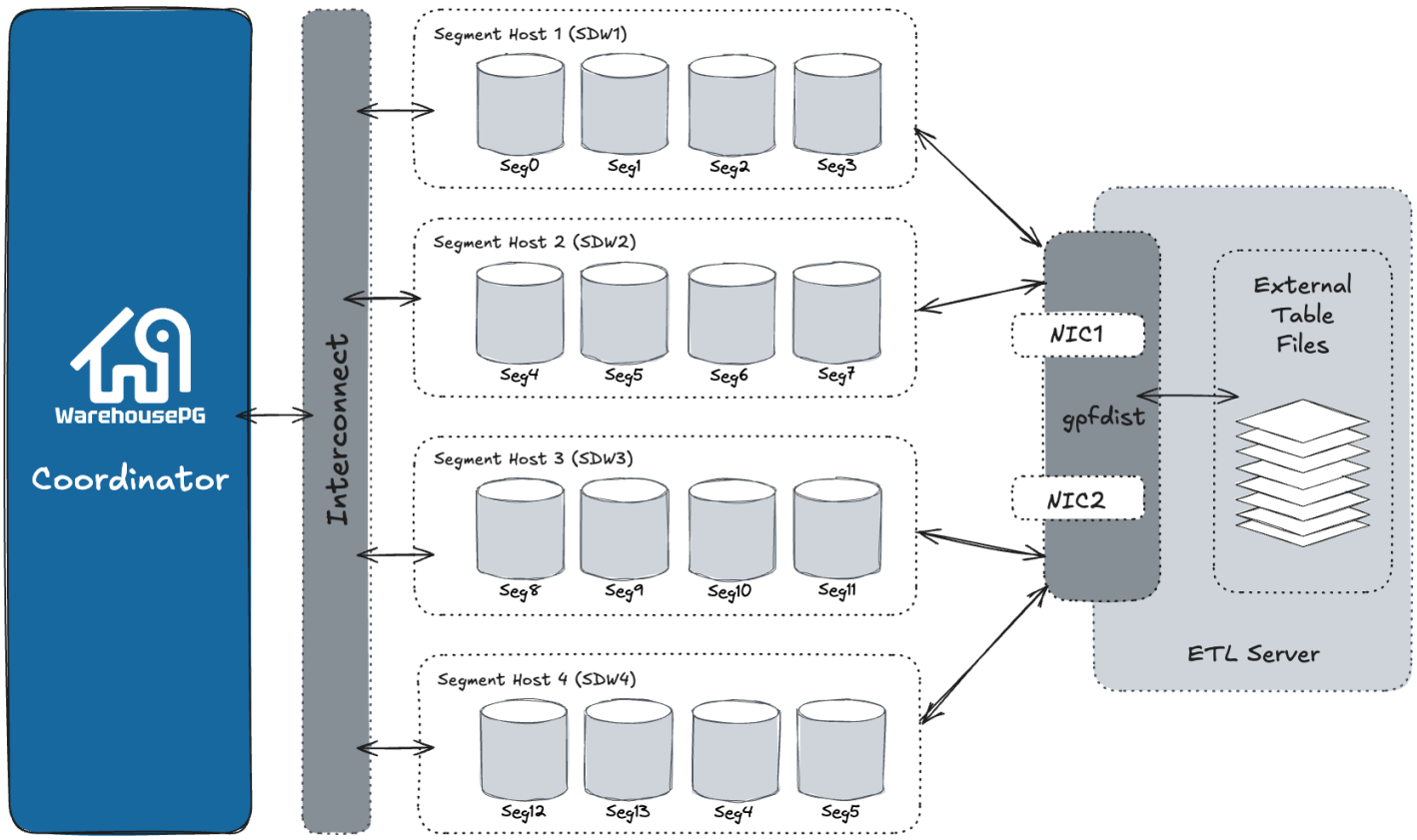
External data files can contain rows in CSV format or any delimited text format supported by the `FORMAT` clause of the `CREATE EXTERNAL TABLE` command. In addition, `gpfdist` can be configured with a YAML-formatted file to transform external data files between a supported text format and another format, for example XML or JSON. See <ref> for an example that shows how to use `gpfdist` to read external XML files into a WarehousePG readable external table.

For readable external tables, `gpfdist` uncompresses `gzip` (`.gz`) and `bzip2` (`.bz2`) files automatically. You can use the wildcard character (*) or other C-style pattern matching to denote multiple files to read. External files are assumed to be relative to the directory specified when you started the `gpfdist` instance.

About gpfdist Setup and Performance

You can run `gpfdist` instances on multiple hosts and you can run multiple `gpfdist` instances on each host. This allows you to deploy `gpfdist` servers strategically so that you can attain fast data load and unload rates by utilizing all of the available network bandwidth and WarehousePG's parallelism.

- Allow network traffic to use all ETL host network interfaces simultaneously. Run one instance of gpfdist for each interface on the ETL host, then declare the host name of each NIC in the `LOCATION` clause of your external table definition (see Examples for Creating External Tables).



- Divide external table data equally among multiple gpfdist instances on the ETL host. For example, on an ETL system with two NICs, run two gpfdist instances (one on each NIC) to optimize data load performance and divide the external table data files evenly between the two gpfdist servers.

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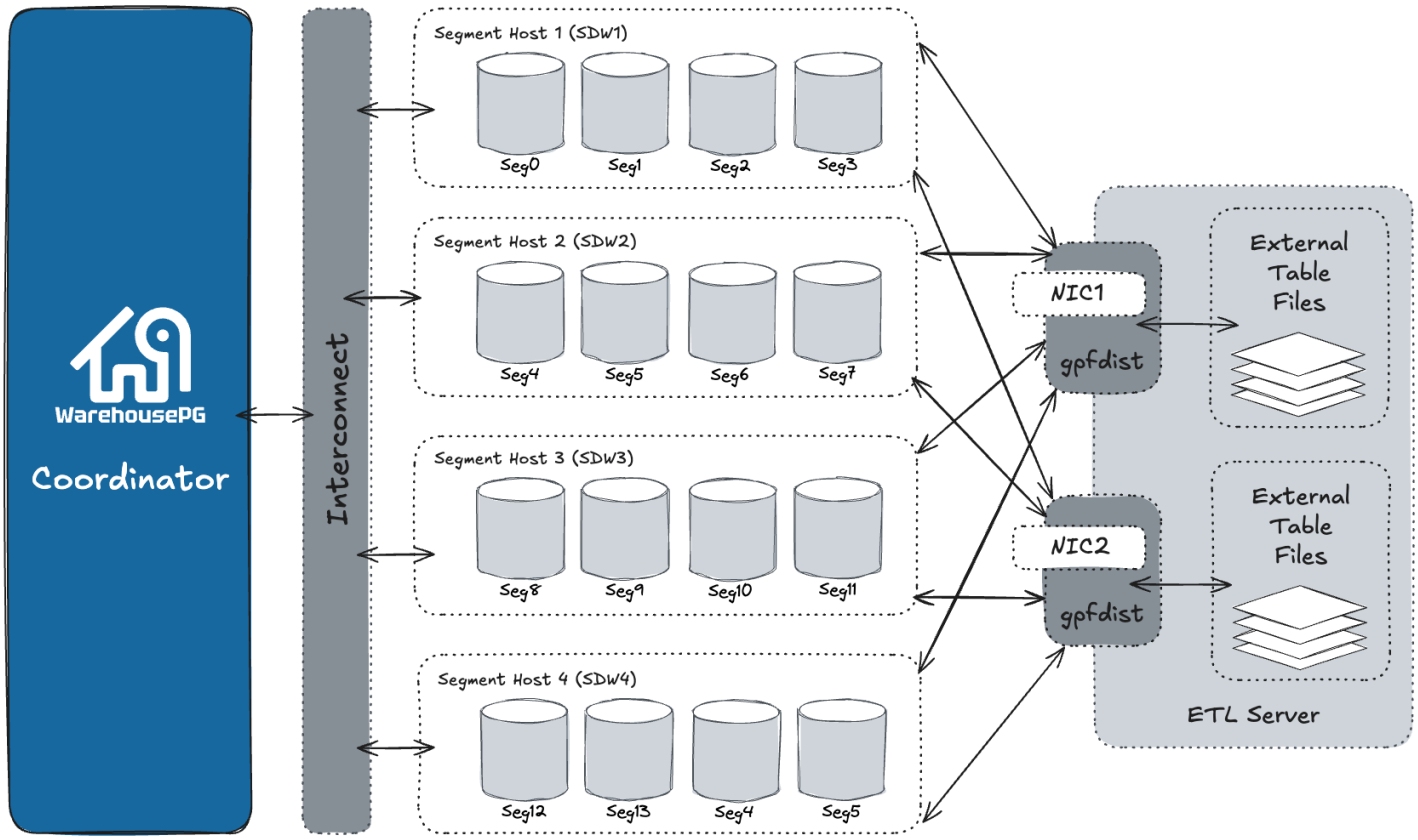

Note Use pipes (|) to separate formatted text when you submit files to gpfdist. WarehousePG encloses comma-separated text strings in single or double quotes. gpfdist has to remove the quotes to parse the strings. Using pipes to separate formatted text avoids the extra step and improves performance.

Controlling Segment Parallelism

The `gp_external_max_segs` server configuration parameter controls the number of segment instances that can access a single gpfdist instance simultaneously. 64 is the default. You can set the number of segments such that some segments process external data files and some perform other database processing. Set this parameter in the `postgresql.conf` file of your coordinator instance.

Installing gpfdist

gpfdist is installed in `$GPHOME/bin` of your WarehousePG coordinator host installation. Run gpfdist on a machine other than the WarehousePG coordinator or standby coordinator, such as on a machine devoted to ETL processing. Running gpfdist on the coordinator or standby coordinator can have a performance impact on query execution. To install gpfdist on your ETL server, get it from the *WarehousePG Clients* package and follow its installation instructions.

Starting and Stopping gpfdist

You can start gpfdist in your current directory location or in any directory that you specify. The default port is `8080`.

From your current directory, type:

```
gpfdist &
```

From a different directory, specify the directory from which to serve files, and optionally, the HTTP port to run on.

To start gpfdist in the background and log output messages and errors to a log file:

```
$ gpfdist -d /var/load_files -p 8081 -l /home/`gpadmin`/log &
```

For multiple gpfdist instances on the same ETL host, use a different base directory and port for each instance. For example:

```
$ gpfdist -d /var/load_files1 -p 8081 -l /home/`gpadmin`/log1 &
$ gpfdist -d /var/load_files2 -p 8082 -l /home/`gpadmin`/log2 &
```

To stop gpfdist when it is running in the background:

First find its process id:

```
$ ps -ef | grep gpfdist
```

Then stop the process, for example (where 3456 is the process ID in this example):

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```
$ kill 3456
```

Troubleshooting gpfdist

The segments access gpfdist at runtime. Ensure that the WarehousePG segment hosts have network access to gpfdist. gpfdist is a web server: test connectivity by running the following command from each host in the WarehousePG cluster (segments and coordinator):

```
$ wget http://<gpfdist_hostname>:<port>/<filename>
```

The `CREATE EXTERNAL TABLE` definition must have the correct host name, port, and file names for gpfdist. Specify file names and paths relative to the directory from which gpfdist serves files (the directory path specified when gpfdist started). See Examples for Creating External Tables.

If you start gpfdist on your system and IPv6 networking is deactivated, gpfdist displays this warning message when testing for an IPv6 port.

```
[WRN gpfdist.c:2050] Creating the socket failed
```

If the corresponding IPv4 port is available, gpfdist uses that port and the warning for IPv6 port can be ignored. To see information about the ports that gpfdist tests, use the `-V` option.

For information about IPv6 and IPv4 networking, see your operating system documentation.

When reading or writing data with the `gpfdist` or `gfdists` protocol, the `gpfdist` utility rejects HTTP requests that do not include `X-GP-PROTO` in the request header. If `X-GP-PROTO` is not detected in the header request `gpfdist` returns a 400 error in the status line of the HTTP response header: `400 invalid request (no gp-proto)`.

WarehousePG includes `X-GP-PROTO` in the HTTP request header to indicate that the request is from WarehousePG.

If the `gpfdist` utility hangs with no read or write activity occurring, you can generate a core dump the next time a hang occurs to help debug the issue. Set the environment variable `GPFDIST_WATCHDOG_TIMER` to the number of seconds of no activity to wait before `gpfdist` is forced to exit. When the environment variable is set and `gpfdist` hangs, the utility stops after the specified number of seconds, creates a core dump, and sends relevant information to the log file.

This example sets the environment variable on a Linux system so that `gpfdist` exits after 300 seconds (5 minutes) of no activity.

```
export GPFDIST_WATCHDOG_TIMER=300
```

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4.9 Loading and Unloading Data

The topics in this section describe methods for loading and writing data into and out of a WarehousePG, and how to format data files.

WarehousePG supports high-performance parallel data loading and unloading, and for smaller amounts of data, single file, non-parallel data import and export.

WarehousePG can read from and write to several types of external data sources, including text files, Hadoop file systems, Amazon S3, and web servers.

- The `COPY` SQL command transfers data between an external text file on the coordinator host, or multiple text files on segment hosts, and a WarehousePG table.
- Readable external tables allow you to query data outside of the database directly and in parallel using SQL commands such as `SELECT` or `JOIN`, or sort external table data, and you can create views for external tables. External tables are often used to load external data into a regular database table using a command such as `CREATE TABLE table AS SELECT * FROM ext_table`.
- External web tables provide access to dynamic data. They can be backed with data from URLs accessed using the HTTP protocol or by the output of an OS script running on one or more segments.
- The `gpfdist` utility is the WarehousePG parallel file distribution program. It is an HTTP server that is used with external tables to allow WarehousePG segments to load external data in parallel, from multiple file systems. You can run multiple instances of `gpfdist` on different hosts and network interfaces and access them in parallel.
- The `gpload` utility automates the steps of a load task using `gpfdist` and a YAML-formatted control file.
- You can create readable and writable external tables with the WarehousePG Platform Extension Framework (PXF), and use these tables to load data into, or offload data from, WarehousePG. For information about using PXF, refer to Accessing External Data with PXF.

The method you choose to load data depends on the characteristics of the source data—its location, size, format, and any transformations required.

In the simplest case, the `COPY` SQL command loads data into a table from a text file that is accessible to the WarehousePG coordinator instance. This requires no setup and provides good performance for smaller amounts of data. With the `COPY` command, the data copied into or out of the database passes between a single file on the coordinator host and the database. This limits the total size of the dataset to the capacity of the file system where the external file resides and limits the data transfer to a single file write stream.

More efficient data loading options for large datasets take advantage of the WarehousePG MPP architecture, using the WarehousePG segments to load data in parallel. These methods allow data to load simultaneously from multiple file systems, through multiple NICs, on multiple hosts, achieving very high data transfer rates. External tables allow you to access external files from within the database as if they are regular database tables. When used with `gpfdist`, the WarehousePG parallel file distribution program, external tables provide full parallelism by using the resources of all WarehousePG segments to load or unload data.

WarehousePG leverages the parallel architecture of the Hadoop Distributed File System to access files on that system.

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4.9.1 Loading Data Using an External Table

Use SQL commands such as `INSERT` and `SELECT` to query a readable external table, the same way that you query a regular database table. For example, to load travel expense data from an external table, `ext_expenses`, into a database table, `expenses_travel`:

```
=# INSERT INTO expenses_travel
    SELECT * from ext_expenses where category='travel';
```

To load all data into a new database table:

```
=# CREATE TABLE expenses AS SELECT * from ext_expenses;
```

Parent topic: Loading and Unloading Data

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4.9.2 Loading and Writing Non-HDFS Custom Data

WarehousePG supports `TEXT` and `CSV` formats for importing and exporting data through external tables. You can load and save data in other formats by defining a custom format or custom protocol or by setting up a transformation with the `gpfdist` parallel file server.

- Using a Custom Format
- Using a Custom Protocol

Parent topic: Loading and Unloading Data

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4.9.2.1 Using a Custom Format

You specify a custom data format in the `FORMAT` clause of `CREATE EXTERNAL TABLE`.

```
FORMAT 'CUSTOM' (formatter=format_function, key1=val1,...keyn=valn)
```

Where the `'CUSTOM'` keyword indicates that the data has a custom format and `formatter` specifies the function to use to format the data, followed by comma-separated parameters to the formatter function.

WarehousePG provides functions for formatting fixed-width data, but you must author the formatter functions for variable-width data. The steps are as follows.

1. Author and compile input and output functions as a shared library.
2. Specify the shared library function with `CREATE FUNCTION` in WarehousePG.
3. Use the `formatter` parameter of `CREATE EXTERNAL TABLE`'s `FORMAT` clause to call the function.

- **Importing and Exporting Fixed Width Data**
- **Examples: Read Fixed-Width Data**

Parent topic: Loading and Writing Non-HDFS Custom Data

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4.9.2.1.1 Importing and Exporting Fixed Width Data

Each column/field in fixed-width text data contains a certain number of character positions. Use a WarehousePG custom format for fixed-width data by specifying the built-in formatter functions `fixedwith_in` (read) and `fixedwidth_out` (write).

The following example creates an external table that specifies the `file` protocol and references a directory. When the external table is `SELECT`ed, WarehousePG invokes the `fixedwidth_in` formatter function to format the data.

```
CREATE READABLE EXTERNAL TABLE students (
    name varchar(20), address varchar(30), age int)
LOCATION ('file://<host>/file/path/')
FORMAT 'CUSTOM' (formatter=fixedwidth_in, name='20', address='30', age='4');
```

The following options specify how to import fixed width data.

- Read all the data.

  To load all of the fields on a line of fixed-width data, you must load them in their physical order. You must specify `<field_name>=<field_lenth>` for each field; you cannot specify a starting and ending position. The field names that you specify in the `FORMAT` options must match the order in which you define the columns in the `CREATE EXTERNAL TABLE` command.

- Set options for blank and null characters.

  Trailing blanks are trimmed by default. To keep trailing blanks, use the `preserve_blanks=on` option. You can reset the trailing blanks option back to the default by specifying the `preserve_blanks=off` option.

  Use the `null='null_string_value'` option to specify a value for null characters.

- If you specify `preserve_blanks=on`, you must also define a value for null characters.

- If you specify `preserve_blanks=off`, null is not defined, and the field contains only blanks, WarehousePG writes a null to the table. If null is defined, WarehousePG writes an empty string to the table.

  Use the `line_delim='line_ending'` option to specify the line ending character. The following examples cover most cases. The `E` specifies an escape string constant.

  ```
  line_delim=E'\n'
  line_delim=E'\r'
  line_delim=E'\r\n'
  line_delim='abc'
  ```

Parent topic: Using a Custom Format

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4.9.2.1.2 Examples of Reading Fixed-Width Data

The following examples show how to read fixed-width data.

Example 1 – Loading a table with all fields defined

```
CREATE READABLE EXTERNAL TABLE students (
name varchar(20), address varchar(30), age int)
LOCATION ('file://<host>/file/path/')
FORMAT 'CUSTOM' (formatter=fixedwidth_in,
         name=20, address=30, age=4);
```

Example 2 – Loading a table with PRESERVED_BLANKS on

```
CREATE READABLE EXTERNAL TABLE students (
name varchar(20), address varchar(30), age int)
LOCATION ('gpfdist://<host>:<portNum>/file/path/')
FORMAT 'CUSTOM' (formatter=fixedwidth_in,
         name=20, address=30, age=4,
        preserve_blanks='on',null='NULL');
```

Example 3 – Loading data with no line delimiter

```
CREATE READABLE EXTERNAL TABLE students (
name varchar(20), address varchar(30), age int)
LOCATION ('file://<host>/file/path/')
FORMAT 'CUSTOM' (formatter=fixedwidth_in,
         name='20', address='30', age='4', line_delim='?@')
```

Example 4 – Create a writable external table with a \r\n line delimiter

```
CREATE WRITABLE EXTERNAL TABLE students_out (
name varchar(20), address varchar(30), age int)
LOCATION ('gpfdist://<host>:<portNum>/file/path/students_out.txt')
FORMAT 'CUSTOM' (formatter=fixedwidth_out,
        name=20, address=30, age=4, line_delim=E'\r\n');
```

Parent topic: Using a Custom Format

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4.9.2.2 Using a Custom Protocol

WarehousePG provides protocols such as gpfdist, `http`, and `file` for accessing data over a network, or you can author a custom protocol. You can use the standard data formats, `TEXT` and `CSV`, or a custom data format with custom protocols.

You can create a custom protocol whenever the available built-in protocols do not suffice for a particular need. For example, you could connect WarehousePG in parallel to another system directly, and stream data from one to the other without the need to materialize the data on disk or use an intermediate process such as gpfdist. You must be a superuser to create and register a custom protocol.

1. Author the send, receive, and (optionally) validator functions in C, with a predefined API. These functions are compiled and registered with the WarehousePG. For an example custom protocol, see Example Custom Data Access Protocol.

2. After writing and compiling the read and write functions into a shared object (.so), declare a database function that points to the .so file and function names.

   The following examples use the compiled import and export code.

   ```
   CREATE FUNCTION myread() RETURNS integer
   as '$libdir/gpextprotocol.so', 'myprot_import'
   LANGUAGE C STABLE;
   CREATE FUNCTION mywrite() RETURNS integer
   as '$libdir/gpextprotocol.so', 'myprot_export'
   LANGUAGE C STABLE;
   ```

   The format of the optional validator function is:

   ```
   CREATE OR REPLACE FUNCTION myvalidate() RETURNS void
   AS '$libdir/gpextprotocol.so', 'myprot_validate'
   LANGUAGE C STABLE;
   ```

3. Create a protocol that accesses these functions. `Validatorfunc` is optional.

   ```
   CREATE TRUSTED PROTOCOL myprot(
   writefunc='mywrite',
   readfunc='myread',
   validatorfunc='myvalidate');
   ```

4. Grant access to any other users, as necessary.

   ```
   GRANT ALL ON PROTOCOL myprot TO otheruser;
   ```

5. Use the protocol in readable or writable external tables.

   ```
   CREATE WRITABLE EXTERNAL TABLE ext_sales(LIKE sales)
   LOCATION ('myprot://<meta>/<meta>/…')
   FORMAT 'TEXT';
   CREATE READABLE EXTERNAL TABLE ext_sales(LIKE sales)
   LOCATION('myprot://<meta>/<meta>/…')
   FORMAT 'TEXT';
   ```

Declare custom protocols with the SQL command `CREATE TRUSTED PROTOCOL`, then use the `GRANT` command to grant access to your users. For example:

- Allow a user to create a readable external table with a trusted protocol

  ```
  GRANT SELECT ON PROTOCOL <protocol name> TO <user name>;
  ```

- Allow a user to create a writable external table with a trusted protocol

  ```
  GRANT INSERT ON PROTOCOL <protocol name> TO <user name>;
  ```

- Allow a user to create readable and writable external tables with a trusted protocol

  ```
  GRANT ALL ON PROTOCOL <protocol name> TO <user name>;
  ```

Parent topic: Loading and Writing Non-HDFS Custom Data

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4.9.3 Handling Load Errors

Readable external tables are most commonly used to select data to load into regular database tables. You use the `CREATE TABLE AS SELECT` or `INSERT INTO` commands to query the external table data. By default, if the data contains an error, the entire command fails and the data is not loaded into the target database table.

The `SEGMENT REJECT LIMIT` clause allows you to isolate format errors in external table data and to continue loading correctly formatted rows. Use `SEGMENT REJECT LIMIT` to set an error threshold, specifying the reject limit `count` as number of `ROWS` (the default) or as a `PERCENT` of total rows (1-100).

The entire external table operation is cancelled, and no rows are processed, if the number of error rows reaches the `SEGMENT REJECT LIMIT`. The limit of error rows is per-segment, not per entire operation. The operation processes all good rows, and it discards and optionally logs formatting errors for erroneous rows, if the number of error rows does not reach the `SEGMENT REJECT LIMIT`.

The `LOG ERRORS` clause allows you to keep error rows for further examination. For information about the `LOG ERRORS` clause, see the `CREATE EXTERNAL TABLE` command in the *WarehousePG Reference Guide*.

When you set `SEGMENT REJECT LIMIT`, WarehousePG scans the external data in single row error isolation mode. Single row error isolation mode applies to external data rows with format errors such as extra or missing attributes, attributes of a wrong data type, or invalid client encoding sequences. WarehousePG does not check constraint errors, but you can filter constraint errors by limiting the `SELECT` from an external table at runtime. For example, to eliminate duplicate key errors:

```
=# INSERT INTO table_with_pkeys
    SELECT DISTINCT * FROM external_table;
```

> **Note** When loading data with the `COPY` command or an external table, the value of the server configuration parameter `gp_initial_bad_row_limit` limits the initial number of rows that are processed that are not formatted properly. The default is to stop processing if the first 1000 rows contain formatting errors. See the *WarehousePG Reference Guide* for information about the parameter.

- Define an External Table with Single Row Error Isolation
- Capture Row Formatting Errors and Declare a Reject Limit
- Viewing Bad Rows in the Error Log
- Moving Data between Tables

Parent topic: Loading and Unloading Data

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4.9.3.1 Define an External Table with Single Row Error Isolation

The following example logs errors internally in WarehousePG and sets an error threshold of 10 errors.

```
=# CREATE EXTERNAL TABLE ext_expenses ( name text,
   date date,  amount float4, category text, desc1 text )
   LOCATION ('gpfdist://etlhost-1:8081/*',
             'gpfdist://etlhost-2:8082/*')
   FORMAT 'TEXT' (DELIMITER '|')
   LOG ERRORS SEGMENT REJECT LIMIT 10
     ROWS;
```

Use the built-in SQL function `gp_read_error_log('external_table')` to read the error log data. This example command displays the log errors for *ext_expenses*:

```
SELECT gp_read_error_log('ext_expenses');
```

For information about the format of the error log, see Viewing Bad Rows in the Error Log.

The built-in SQL function `gp_truncate_error_log('external_table')` deletes the error data. This example deletes the error log data created from the previous external table example :

```
SELECT gp_truncate_error_log('ext_expenses');
```

Parent topic: Handling Load Errors

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4.9.3.2 Capture Row Formatting Errors and Declare a Reject Limit

The following SQL fragment captures formatting errors internally in WarehousePG and declares a reject limit of 10 rows.

```
LOG ERRORS SEGMENT REJECT LIMIT 10 ROWS
```

Use the built-in SQL function `gp_read_error_log()` to read the error log data. For information about viewing log errors, see Viewing Bad Rows in the Error Log.

Parent topic: Handling Load Errors

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4.9.3.3 Viewing Bad Rows in the Error Log

If you use single row error isolation (see Define an External Table with Single Row Error Isolation or Running COPY in Single Row Error Isolation Mode), any rows with formatting errors are logged internally by WarehousePG.

WarehousePG captures the following error information in a table format:

column	type	description
cmdtime	timestamptz	Timestamp when the error occurred.
relname	text	The name of the external table or the target table of a `COPY` command.
filename	text	The name of the load file that contains the error.
linenum	int	If `COPY` was used, the line number in the load file where the error occurred. For external tables using file:// protocol or gpfdist:// protocol and CSV format, the file name and line number is logged.
bytenum	int	For external tables with the gpfdist:// protocol and data in TEXT format: the byte offset in the load file where the error occurred. gpfdist parses TEXT files in blocks, so logging a line number is not possible. CSV files are parsed a line at a time so line number tracking is possible for CSV files.
errmsg	text	The error message text.
rawdata	text	The raw data of the rejected row.
rawbytes	bytea	In cases where there is a database encoding error (the client encoding used cannot be converted to a server-side encoding), it is not possible to log the encoding error as *rawdata*. Instead the raw bytes are stored and you will see the octal code for any non seven bit ASCII characters.

You can use the WarehousePG built-in SQL function `gp_read_error_log()` to display formatting errors that are logged internally. For example, this command displays the error log information for the table *ext_expenses*:

```
SELECT gp_read_error_log('ext_expenses');
```

For information about managing formatting errors that are logged internally, see the command `COPY` or `CREATE EXTERNAL TABLE` in the *WarehousePG Reference Guide*.

Parent topic: Handling Load Errors

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4.9.3.4 Moving Data between Tables

You can use `CREATE TABLE AS` or `INSERT...SELECT` to load external and external web table data into another (non-external) database table, and the data will be loaded in parallel according to the external or external web table definition.

If an external table file or external web table data source has an error, one of the following will happen, depending on the isolation mode used:

- **Tables without error isolation mode**: any operation that reads from that table fails. Loading from external and external web tables without error isolation mode is an all or nothing operation.
- **Tables with error isolation mode**: the entire file will be loaded, except for the problematic rows (subject to the configured REJECT_LIMIT)

Parent topic: Handling Load Errors

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4.9.4 Loading Data with gpload

The WarehousePG `gpload` utility loads data using readable external tables and the WarehousePG parallel file server (gpfdist or `gpfdists`). It handles parallel file-based external table setup and allows users to configure their data format, external table definition, and gpfdist or `gpfdists` setup in a single configuration file.

> **Note** `gpfdist` and `gpload` are compatible only with the WarehousePG major version in which they are shipped. For example, a `gpfdist` utility that is installed with WarehousePG 6.x cannot be used with WarehousePG 7.x.

> **Note** `MERGE` and `UPDATE` operations are not supported if the target table column name is a reserved keyword, has capital letters, or includes any character that requires quotes (" ") to identify the column.

To use gpload

1. Ensure that your environment is set up to run `gpload`. Some dependent files from your WarehousePG installation are required, such as gpfdist and Python 3, as well as network access to the WarehousePG segment hosts. On Windows clients, `gpload` also requires that you install the following packages:

   ```
   pip install psycopg2 pyyaml
   ```

2. Create your load control file. This is a YAML-formatted file that specifies the WarehousePG connection information, gpfdist configuration information, external table options, and data format.

   See the *WarehousePG Reference Guide* for details.

   For example:

   ```
   ---
   VERSION: 1.0.0.1
   DATABASE: ops
   USER: gpadmin
   HOST: cdw-1
   PORT: 5432
   GPLOAD:
      INPUT:
       - SOURCE:
            LOCAL_HOSTNAME:
              - etl1-1
              - etl1-2
              - etl1-3
              - etl1-4
            PORT: 8081
            FILE:
              - /var/load/data/*
       - COLUMNS:
              - name: text
              - amount: float4
              - category: text
              - descr: text
              - date: date
       - FORMAT: text
       - DELIMITER: '|'
       - ERROR_LIMIT: 25
       - LOG_ERRORS: true
      OUTPUT:
       - TABLE: payables.expenses
       - MODE: INSERT
      PRELOAD:
       - REUSE_TABLES: true
   SQL:
      - BEFORE: "INSERT INTO audit VALUES('start', current_timestamp)"
      - AFTER: "INSERT INTO audit VALUES('end', current_timestamp)"
   ```

3. Run `gpload`, passing in the load control file. For example:

   ```
   gpload -f my_load.yml
   ```

Parent topic: Loading and Unloading Data

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4.9.5 Transforming External Data with gpfdist and gpload

The `gpfdist` parallel file server allows you to set up transformations that enable WarehousePG external tables to read and write files in formats that are not supported with the `CREATE EXTERNAL TABLE` command's `FORMAT` clause. An *input* transformation reads a file in the foreign data format and outputs rows to `gpfdist` in the CSV or other text format specified in the external table's `FORMAT` clause. An *output* transformation receives rows from `gpfdist` in text format and converts them to the foreign data format.

> **Note** `gpfdist` and `gpload` are compatible only with the WarehousePG major version in which they are shipped. For example, a `gpfdist` utility that is installed with WarehousePG 6.x cannot be used with WarehousePG 7.x.

This topic describes the tasks to set up data transformations that work with `gpfdist` to read or write external data files with formats that WarehousePG does not support.

- About gpfdist Transformations
- Determine the Transformation Schema
- Write a Transformation
- Write the gpfdist Configuration File
- Transfer the Data
- Configuration File Format
- XML Transformation Examples

Parent topic: Loading and Unloading Data

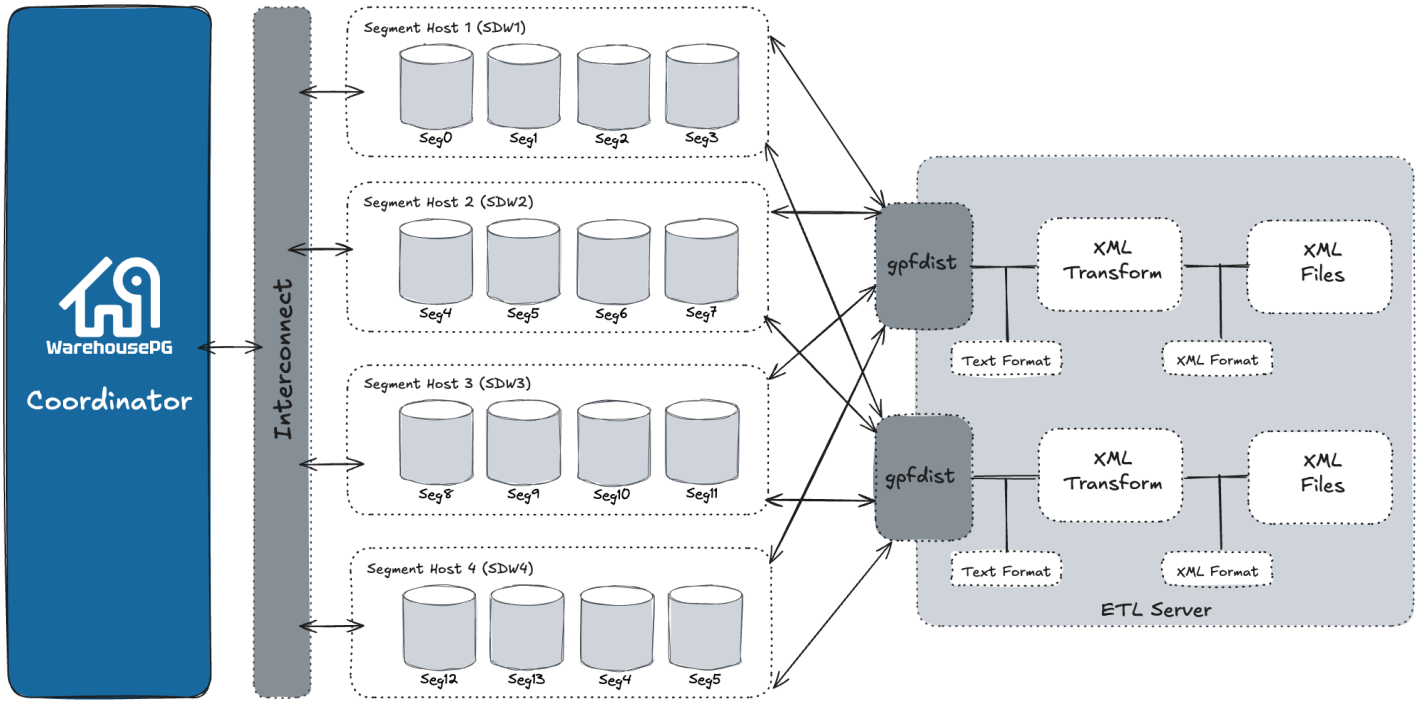
About gpfdist Transformations

To set up a transformation for a data format, you provide an executable command that `gpfdist` can call with the name of the file containing data. For example, you could write a shell script that runs an XSLT transformation on an XML file to output rows with columns delimited with a vertical bar (`|`) character and rows delimited with linefeeds.

Transformations are configured in a YAML-formatted configuration file passed to `gpfdist` on the command line.

If you want to load the external data into a table in the WarehousePG, you can use the `gpload` utility to automate the tasks to create an external table, run `gpfdist` , and load the transformed data into the database table.

Accessing data in external XML files from within the database is a common example requiring transformation. The following diagram shows *gpfdist* performing a transformation on XML files on an ETL server.



Following are the high-level steps to set up a `gpfdist` transformation for external data files. The process is illustrated with an XML example.

1. Determine the transformation schema.
2. Write a transformation.
3. Write the gpfdist configuration file.
4. Transfer the data.

Determine the Transformation Schema

To prepare for the transformation project:

1. Determine the goal of the project, such as indexing data, analyzing data, combining data, and so on.
2. Examine the source files and note the file structure and element names.
3. Choose the elements to import and decide if any other limits are appropriate.

For example, the following XML file, *prices.xml*, is a simple XML file that contains price records. Each price record contains two fields: an item number and a price.

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```
<?xml version="1.0" encoding="ISO-8859-1" ?>
<prices>
  <pricerecord>
    <itemnumber>708421</itemnumber>
    <price>19.99</price>
  </pricerecord>
  <pricerecord>
    <itemnumber>708466</itemnumber>
    <price>59.25</price>
  </pricerecord>
  <pricerecord>
    <itemnumber>711121</itemnumber>
    <price>24.99</price>
  </pricerecord>
</prices>
```

The goal of this transformation is to import all the data into a WarehousePG readable external table with an integer `itemnumber` column and a decimal `price` column.

Write a Transformation

The transformation specifies what to extract from the data. You can use any authoring environment and language appropriate for your project. For XML transformations choose from technologies such as XSLT, Joost (STX), Java, Python, or Perl, based on the goals and scope of the project.

In the price example, the next step is to transform the XML data into a two-column delimited text format.

```
708421|19.99
708466|59.25
711121|24.99
```

The following STX transform, called *input_transform.stx*, performs the data transformation.

```
<?xml version="1.0"?>
<stx:transform version="1.0"
   xmlns:stx="http://stx.sourceforge.net/2002/ns"
   pass-through="none">
  <!-- declare variables -->
  <stx:variable name="itemnumber"/>
  <stx:variable name="price"/>
  <!-- match and output prices as columns delimited by | -->
  <stx:template match="/prices/pricerecord">
    <stx:process-children/>
    <stx:value-of select="$itemnumber"/>
<stx:text>|</stx:text>
    <stx:value-of select="$price"/>      <stx:text>
</stx:text>
  </stx:template>
  <stx:template match="itemnumber">
    <stx:assign name="itemnumber" select="."/>
  </stx:template>
  <stx:template match="price">
    <stx:assign name="price" select="."/>
  </stx:template>
</stx:transform>
```

This STX transform declares two temporary variables, `itemnumber` and `price`, and the following rules.

1. When an element that satisfies the XPath expression `/prices/pricerecord` is found, examine the child elements and generate output that contains the value of the `itemnumber` variable, a `|` character, the value of the price variable, and a newline.
2. When an `<itemnumber>` element is found, store the content of that element in the variable `itemnumber`.
3. When a <price> element is found, store the content of that element in the variable `price`.

Write the gpfdist Configuration File

The gpfdist configuration is specified as a YAML 1.1 document. It contains rules that gpfdist uses to select a transformation to apply when loading or extracting data.

This example gpfdist configuration contains the following items that are required for the *prices.xml* transformation scenario:

- the `config.yaml` file defining `TRANSFORMATIONS`
- the `input_transform.sh` wrapper script, referenced in the `config.yaml` file
- the `input_transform.stx` joost transformation, called from `input_transform.sh`

Aside from the ordinary YAML rules, such as starting the document with three dashes (`---`), a gpfdist configuration must conform to the following restrictions:

1. A `VERSION` setting must be present with the value `1.0.0.1`.
2. A `TRANSFORMATIONS` setting must be present and contain one or more mappings.
3. Each mapping in the `TRANSFORMATION` must contain:
    - a `TYPE` with the value 'input' or 'output'
    - a `COMMAND` indicating how the transformation is run.
4. Each mapping in the `TRANSFORMATION` can contain optional `CONTENT`, `SAFE`, and `STDERR` settings.

The following gpfdist configuration, called `config.yaml`, applies to the prices example. The initial indentation on each line is significant and reflects the hierarchical nature of the specification. The transformation name `prices_input` in the following example will be referenced later when creating the table in SQL.

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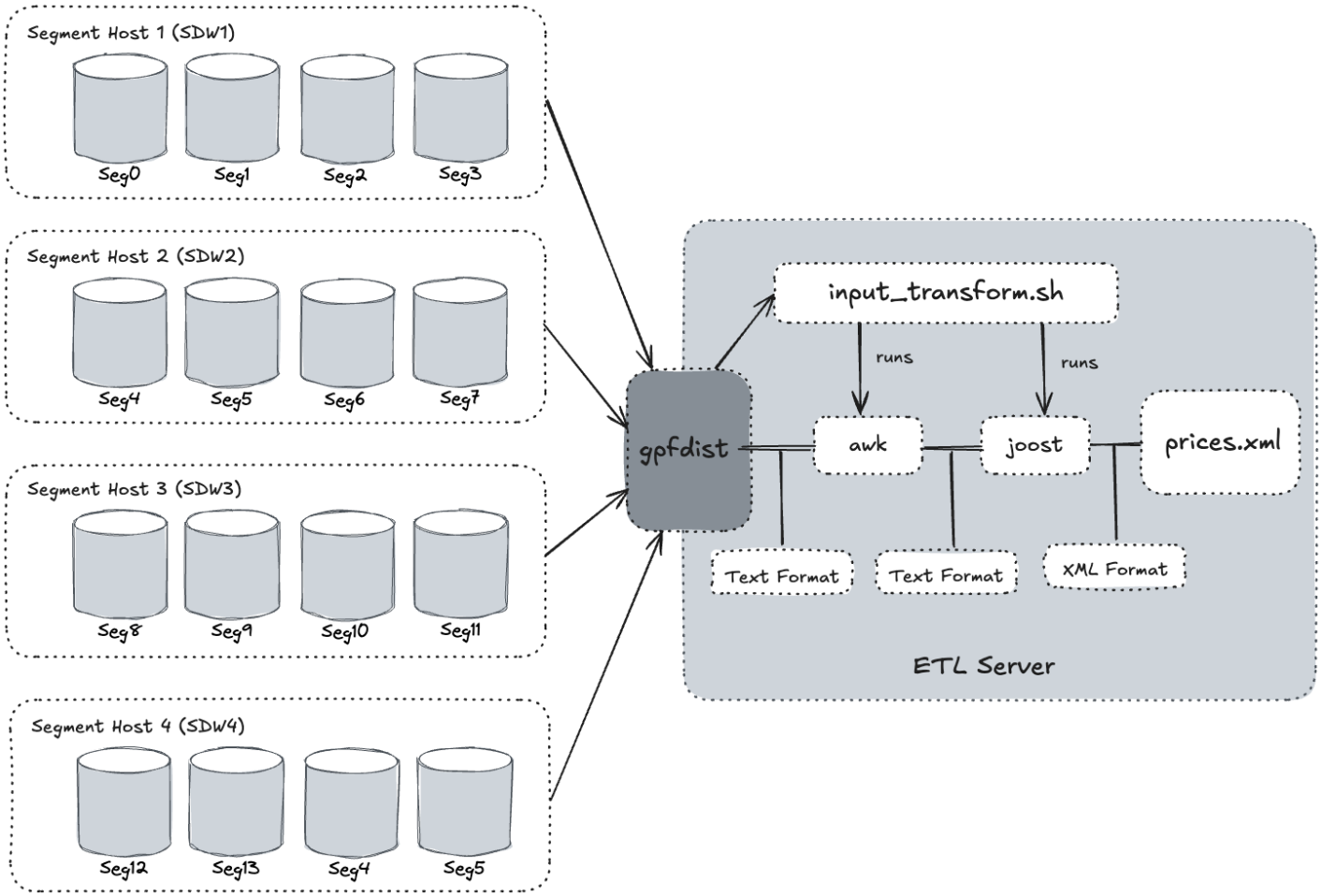
```
---
VERSION: 1.0.0.1
TRANSFORMATIONS:
  prices_input:
    TYPE  input
    COMMAND:  /bin/bash input_transform.sh %filename%
```

The `COMMAND` setting uses a wrapper script called `input_transform.sh` with a `%filename%` placeholder. When gpfdist runs the `prices_input` transform, it invokes `input_transform.sh` with `/bin/bash` and replaces the `%filename%` placeholder with the path to the input file to transform. The wrapper script called `input_transform.sh` contains the logic to invoke the STX transformation and return the output.

If Joost is used, the Joost STX engine must be installed.

```
#!/bin/bash
# input_transform.sh - sample input transformation,
# demonstrating use of Java and Joost STX to convert XML into
# text to load into WarehousePG.
# java arguments:
#   -jar joost.jar         joost STX engine
#   -nodecl                  don't generate a <?xml?> declaration
#   $1                        filename to process
#   input_transform.stx    the STX transformation
#
# the AWK step eliminates a blank line joost emits at the end
java \
    -jar joost.jar \
    -nodecl \
    $1 \
    input_transform.stx \
 | awk 'NF>0'
```

The `input_transform.sh` file uses the Joost STX engine with the AWK interpreter. The following diagram shows the process flow as gpfdist runs the transformation.



Transfer the Data

Create the target database tables with SQL statements based on the appropriate schema.

There are no special requirements for WarehousePG tables that hold loaded data. In the prices example, the following command creates the `prices` table, where the data is to be loaded.

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```
CREATE TABLE prices (
  itemnumber integer,
  price       decimal
)
DISTRIBUTED BY (itemnumber);
```

Next, use one of the following approaches to transform the data with gpfdist.

- `gpload` supports only input transformations, but in many cases is easier to implement.
- `gpfdist` with `INSERT INTO SELECT FROM` supports both input and output transformations, but exposes details that `gpload` automates for you.

Transforming with gpload

The WarehousePG `gpload` utility orchestrates a data load operation using the `gpfdist` parallel file server and a YAML-formatted configuration file. `gpload` automates these tasks:

- Creates a readable external table in the database.
- Starts `gpfdist` instances with the configuration file that contains the transformation.
- Runs `INSERT INTO table\_name SELECT FROM external\_table` to load the data.
- Removes the external table definition.

Transforming data with `gpload` requires that the settings `TRANSFORM` and `TRANSFORM_CONFIG` appear in the `INPUT` section of the `gpload` control file.

For more information about the syntax and placement of these settings in the `gpload` control file, see the *WarehousePG Reference Guide*.

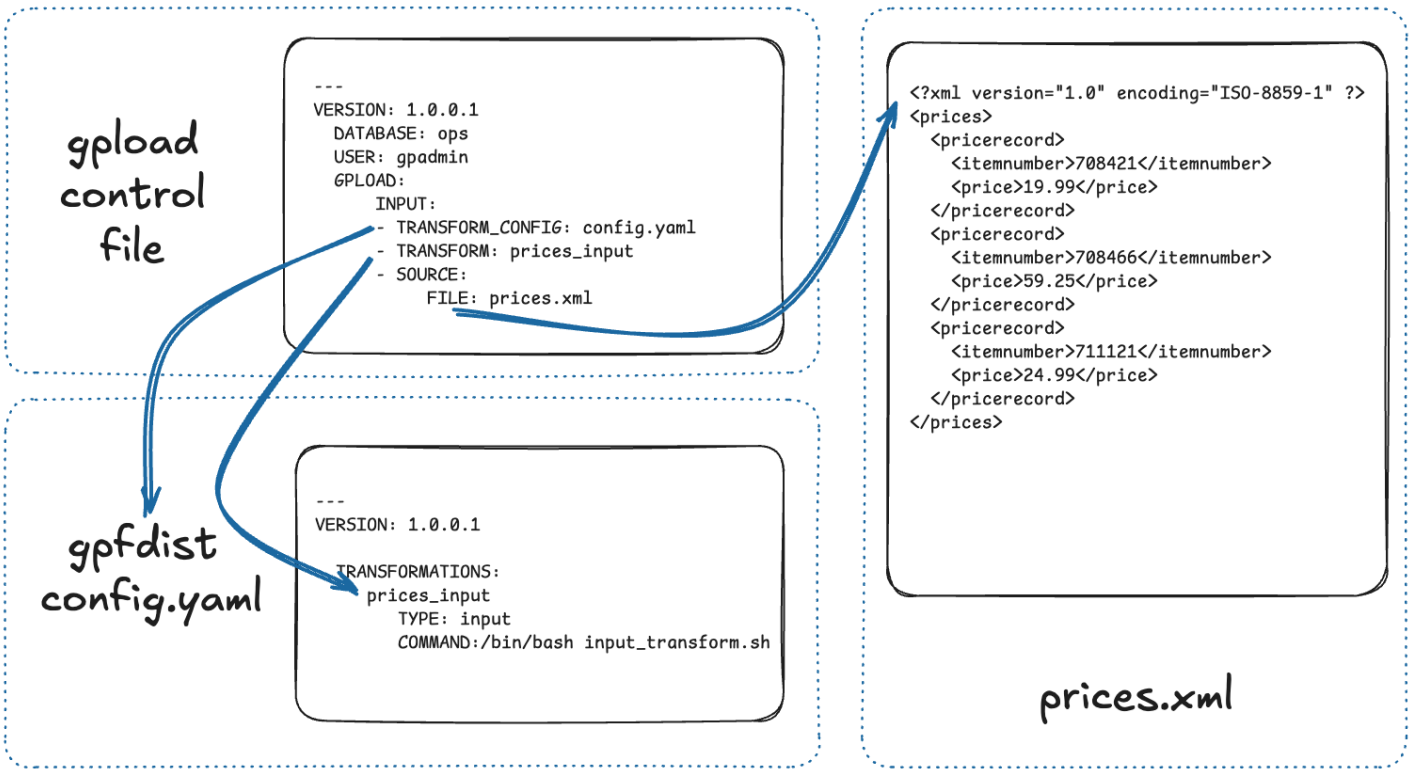
- `TRANSFORM_CONFIG` specifies the name of the gpfdist configuration file.
- The `TRANSFORM` setting indicates the name of the transformation that is described in the file named in `TRANSFORM_CONFIG`.

```
---
VERSION: 1.0.0.1
DATABASE: ops
USER: gpadmin
GPLOAD:
  INPUT:
    - TRANSFORM_CONFIG: config.yaml
    - TRANSFORM: prices_input
    - SOURCE:
        FILE: prices.xml
```

The transformation name must appear in two places: in the `TRANSFORM` setting of the gpfdist configuration file and in the `TRANSFORMATIONS` section of the file named in the `TRANSFORM_CONFIG` section.

In the `gpload` control file, the optional parameter `MAX_LINE_LENGTH` specifies the maximum length of a line in the XML transformation data that is passed to `gpload`.

The following diagram shows the relationships between the `gpload` control file, the gpfdist configuration file, and the XML data file.



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Transforming with gpfdist and INSERT INTO SELECT FROM

With this load method, you perform each of the tasks that `gpload` automates. You start `gpfdist`, create an external table, load the data, and clean up by dropping the table and stopping `gpfdist`.

Specify the transformation in the `CREATE EXTERNAL TABLE` definition's `LOCATION` clause. For example, the transform is shown in bold in the following command. (Run gpfdist first, using the command `gpfdist -c config.yaml`).

```
CREATE READABLE EXTERNAL TABLE prices_readable (LIKE prices)
   LOCATION ('gpfdist://hostname:8080/prices.xml#transform=prices_input')
   FORMAT 'TEXT' (DELIMITER '|')
   LOG ERRORS SEGMENT REJECT LIMIT 10;
```

In the command above, change `hostname` to your hostname. `prices_input` comes from the `gpfdist` configuration file.

The following query then loads the data into the `prices` table.

```
INSERT INTO prices SELECT * FROM prices_readable;
```

Configuration File Format

The gpfdist configuration file uses the YAML 1.1 document format and implements a schema for defining the transformation parameters. The configuration file must be a valid YAML document.

The gpfdist program processes the document in order and uses indentation (spaces) to determine the document hierarchy and relationships of the sections to one another. The use of white space is significant. Do not use white space for formatting and do not use tabs.

The following is the basic structure of a configuration file.

```
---
VERSION1.0.0.1
TRANSFORMATIONS:
  transformation_name1:
    TYPE   input | output
    COMMANDcommand
    CONTENTdata | paths
    SAFE   posix-regex
    STDERR server | console
  transformation_name2:
    TYPE   input | output
    COMMANDcommand
...
```

VERSION Required. The version of the gpfdist configuration file schema. The current version is 1.0.0.1.

TRANSFORMATIONS Required. Begins the transformation specification section. A configuration file must have at least one transformation. When gpfdist receives a transformation request, it looks in this section for an entry with the matching transformation name.

TYPE Required. Specifies the direction of transformation. Values are `input` or `output`.

- `input`: gpfdist treats the standard output of the transformation process as a stream of records to load into WarehousePG.
- `output`: gpfdist treats the standard input of the transformation process as a stream of records from WarehousePG to transform and write to the appropriate output.

COMMAND Required. Specifies the command gpfdist will run to perform the transformation.

For input transformations, gpfdist invokes the command specified in the `CONTENT` setting. The command is expected to open the underlying file(s) as appropriate and produce one line of `TEXT` for each row to load into WarehousePG. The input transform determines whether the entire content should be converted to one row or to multiple rows.

For output transformations, gpfdist invokes this command as specified in the `CONTENT` setting. The output command is expected to open and write to the underlying file(s) as appropriate. The output transformation determines the final placement of the converted output.

CONTENT Optional. The values are `data` and `paths`. The default value is `data`.

- When `CONTENT` specifies `data`, the text `%filename%` in the `COMMAND` section is replaced by the path to the file to read or write.
- When `CONTENT` specifies `paths`, the text `%filename%` in the `COMMAND` section is replaced by the path to the temporary file that contains the list of files to read or write.

The following is an example of a `COMMAND` section showing the text `%filename%` that is replaced.

```
COMMAND: /bin/bash input_transform.sh %filename%
```

SAFE Optional. A `POSIX` regular expression that the paths must match to be passed to the transformation. Specify `SAFE` when there is a concern about injection or improper interpretation of paths passed to the command. The default is no restriction on paths.

STDERR Optional. The values are `server` and `console`.

This setting specifies how to handle standard error output from the transformation. The default, `server`, specifies that gpfdist will capture the standard error output from the transformation in a temporary file and send the first 8k of that file to WarehousePG as an error message. The error message will appear as an SQL error. `Console` specifies that gpfdist does not redirect or transmit the standard error output from the transformation.

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XML Transformation Examples

The following examples demonstrate the complete process for different types of XML data and STX transformations. Files and detailed instructions associated with these examples are in the GitHub repo `https://github.com/warehouse-pg/warehouse-pg` in the gpMgmt/demo/gpfdist_transform directory. Read the README file in the *Before You Begin* section before you run the examples. The README file explains how to download the example data file used in the examples.

Command-based External Web Tables

The output of a shell command or script defines command-based web table data. Specify the command in the `EXECUTE` clause of `CREATE EXTERNAL WEB TABLE`. The data is current as of the time the command runs. The `EXECUTE` clause runs the shell command or script on the specified coordinator, and/or segment host or hosts. The command or script must reside on the hosts corresponding to the host(s) defined in the `EXECUTE` clause.

By default, the command is run on segment hosts when active segments have output rows to process. For example, if each segment host runs four primary segment instances that have output rows to process, the command runs four times per segment host. You can optionally limit the number of segment instances that run the web table command. All segments included in the web table definition in the `ON` clause run the command in parallel.

The command that you specify in the external table definition runs from the database and cannot access environment variables from `.bashrc` or `.profile`. Set environment variables in the `EXECUTE` clause. For example:

```
=# CREATE EXTERNAL WEB TABLE output (output text)
    EXECUTE 'PATH=/home/gpadmin/programs; export PATH; myprogram.sh'
    FORMAT 'TEXT';
```

Scripts must be executable by the `gpadmin` user and reside in the same location on the coordinator or segment hosts.

The following command defines a web table that runs a script. The script runs on each segment host where a segment has output rows to process.

```
=# CREATE EXTERNAL WEB TABLE log_output
    (linenum int, message text)
    EXECUTE '/var/load_scripts/get_log_data.sh' ON HOST
    FORMAT 'TEXT' (DELIMITER '|');
```

IRS MeF XML Files (In demo Directory)

This example demonstrates loading a sample IRS Modernized eFile tax return using a Joost STX transformation. The data is in the form of a complex XML file.

The U.S. Internal Revenue Service (IRS) made a significant commitment to XML and specifies its use in its Modernized e-File (MeF) system. In MeF, each tax return is an XML document with a deep hierarchical structure that closely reflects the particular form of the underlying tax code.

XML, XML Schema and stylesheets play a role in their data representation and business workflow. The actual XML data is extracted from a ZIP file attached to a MIME "transmission file" message. For more information about MeF, see Modernized e-File (Overview) on the IRS web site.

The sample XML document, *RET990EZ_2006.xml*, is about 350KB in size with two elements:

- ReturnHeader
- ReturnData

The <ReturnHeader> element contains general details about the tax return such as the taxpayer's name, the tax year of the return, and the preparer. The <ReturnData> element contains multiple sections with specific details about the tax return and associated schedules.

The following is an abridged sample of the XML file.

```
<?xml version="1.0" encoding="UTF-8"?>
<Return returnVersion="2006v2.0"
   xmlns="https://www.irs.gov/efile"
   xmlns:efile="https://www.irs.gov/efile"
   xsi:schemaLocation="https://www.irs.gov/efile"
   xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance">
   <ReturnHeader binaryAttachmentCount="1">
     <ReturnId>AAAAAAAAAAAAAAAAAAAA</ReturnId>
     <Timestamp>1999-05-30T12:01:01+05:01</Timestamp>
     <ReturnType>990EZ</ReturnType>
     <TaxPeriodBeginDate>2005-01-01</TaxPeriodBeginDate>
     <TaxPeriodEndDate>2005-12-31</TaxPeriodEndDate>
     <Filer>
       <EIN>011248772</EIN>
       ... more data ...
     </Filer>
     <Preparer>
       <Name>Percy Polar</Name>
       ... more data ...
     </Preparer>
     <TaxYear>2005</TaxYear>
   </ReturnHeader>
   ... more data ..
```

The goal is to import all the data into a WarehousePG. First, convert the XML document into text with newlines "escaped", with two columns: `ReturnId` and a single column on the end for the entire MeF tax return. For example:

```
AAAAAAAAAAAAAAAAAAAA|<Return returnVersion="2006v2.0"...
```

Load the data into WarehousePG.

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WITSML™ Files (In demo Directory)

This example demonstrates loading sample data describing an oil rig using a Joost STX transformation. The data is in the form of a complex XML file downloaded from energistics.org.

The Wellsite Information Transfer Standard Markup Language (WITSML™) is an oil industry initiative to provide open, non-proprietary, standard interfaces for technology and software to share information among oil companies, service companies, drilling contractors, application vendors, and regulatory agencies. For more information about WITSML™, see https://www.energistics.org/.

The oil rig information consists of a top level `<rigs>` element with multiple child elements such as `<documentInfo>, <rig>`, and so on. The following excerpt from the file shows the type of information in the `<rig>` tag.

```
<?xml version="1.0" encoding="UTF-8"?>
<?xml-stylesheet href="../stylesheets/rig.xsl" type="text/xsl" media="screen"?>
<rigs
 xmlns="https://www.energistics.org/schemas/131"
 xmlns:xsi="https://www.w3.org/2001/XMLSchema-instance"
 xsi:schemaLocation="https://www.energistics.org/schemas/131 ../obj_rig.xsd"
 version="1.3.1.1">
 <documentInfo>
 ... misc data ...
 </documentInfo>
 <rig uidWell="W-12" uidWellbore="B-01" uid="xr31">
     <nameWell>6507/7-A-42</nameWell>
     <nameWellbore>A-42</nameWellbore>
     <name>Deep Drill #5</name>
     <owner>Deep Drilling Co.</owner>
     <typeRig>floater</typeRig>
     <manufacturer>Fitsui Engineering</manufacturer>
     <yearEntService>1980</yearEntService>
     <classRig>ABS Class A1 M CSDU AMS ACCU</classRig>
     <approvals>DNV</approvals>
 ... more data ...
```

The goal is to import the information for this rig into WarehousePG.

The sample document, *rig.xml*, is about 11KB in size. The input does not contain tabs so the relevant information can be converted into records delimited with a pipe (|).

```
W-12|6507/7-A-42|xr31|Deep Drill #5|Deep Drilling Co.|John Doe|John.Doe@example.com|
```

With the columns:

- `well_uid text`, -- e.g. W-12
- `well_name text`, -- e.g. 6507/7-A-42
- `rig_uid text`, -- e.g. xr31
- `rig_name text`, -- e.g. Deep Drill #5
- `rig_owner text`, -- e.g. Deep Drilling Co.
- `rig_contact text`, -- e.g. John Doe
- `rig_email text`, -- e.g. John.Doe@example.com
- `doc xml`

Then, load the data into WarehousePG.

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4.9.6 Loading Data with COPY

`COPY FROM` copies data from a file or standard input into a table and appends the data to the table contents. `COPY` is non-parallel: data is loaded in a single process using the WarehousePG coordinator instance. Using `COPY` is only recommended for very small data files.

The `COPY` source file must be accessible to the `postgres` process on the coordinator host. Specify the `COPY` source file name relative to the data directory on the coordinator host, or specify an absolute path.

WarehousePG copies data from `STDIN` or `STDOUT` using the connection between the client and the coordinator server.

Parent topic: Loading and Unloading Data

Loading From a File

The `COPY` command asks the `postgres` backend to open the specified file, read it and append it to the table. In order to be able to read the file, the backend needs to have read permissions on the file, and the file name must be specified using an absolute path on the coordinator host, or a relative path to the coordinator data directory.

```
COPY <table_name> FROM </path/to/filename>;
```

Loading From STDIN

To avoid the problem of copying the data file to the coordinator host before loading the data, `COPY FROM STDIN` uses the Standard Input channel and feeds data directly into the `postgres` backend. After the `COPY FROM STDIN` command started, the backend will accept lines of data until a single line only contains a backslash-period (\.).

```
COPY <table_name> FROM <STDIN>;
```

Loading Data Using \copy in psql

Do not confuse the psql `\copy` command with the `COPY` SQL command. The `\copy` invokes a regular `COPY FROM STDIN` and sends the data from the psql client to the backend. Therefore any file must reside on the host where the psql client runs, and must be accessible to the user which runs the client.

To avoid the problem of copying the data file to the coordinator host before loading the data, `COPY FROM STDIN` uses the Standard Input channel and feeds data directly into the `postgres` backend. After the `COPY FROM STDIN` command started, the backend will accept lines of data until a single line only contains a backslash-period (\.). psql is wrapping all of this into the handy `\copy` command.

```
\copy <table_name> FROM <filename>;
```

Input Format

`COPY FROM` accepts a `FORMAT` parameter, which specifies the format of the input data. The possible values are `TEXT`, `CSV` (Comma Separated Values), and `BINARY`.

```
COPY <table_name> FROM </path/to/filename> WITH (FORMAT csv);
```

The `FORMAT csv` will read comma-separated values. The `FORMAT text` by default uses tabulators to separate the values, the `DELIMITER` option specifies a different character as value delimiter.

```
COPY <table_name> FROM </path/to/filename> WITH (FORMAT text, DELIMITER '|');
```

By default, the default client encoding is used, this can be changed with the `ENCODING` option. This is useful if data is coming from another operating system.

```
COPY <table_name> FROM </path/to/filename> WITH (ENCODING 'latin1');
```

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4.9.7 Running COPY in Single Row Error Isolation Mode

By default, `COPY` stops an operation at the first error: if the data contains an error, the operation fails and no data loads. If you run `COPY FROM` in *single row error isolation mode*, WarehousePG skips rows that contain format errors and loads properly formatted rows. Single row error isolation mode applies only to rows in the input file that contain format errors. If the data contains a constraint error such as violation of a `NOT NULL`, `CHECK`, or `UNIQUE` constraint, the operation fails and no data loads.

Specifying `SEGMENT REJECT LIMIT` runs the `COPY` operation in single row error isolation mode. Specify the acceptable number of error rows on each segment, after which the entire `COPY FROM` operation fails and no rows load. The error row count is for each WarehousePG segment, not for the entire load operation.

If the `COPY` operation does not reach the error limit, WarehousePG loads all correctly-formatted rows and discards the error rows. Use the `LOG ERRORS` clause to capture data formatting errors internally in WarehousePG. For example:

```
=> COPY country FROM '/data/gpdb/country_data'
   WITH DELIMITER '|' LOG ERRORS
   SEGMENT REJECT LIMIT 10 ROWS;
```

See Viewing Bad Rows in the Error Log for information about investigating error rows.

Parent topic: Loading and Unloading Data

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4.9.8 Optimizing Data Load and Query Performance

Use the following tips to help optimize your data load and subsequent query performance.

- Drop indexes before loading data into existing tables.

  Creating an index on pre-existing data is faster than updating it incrementally as each row is loaded. You can temporarily increase the `maintenance_work_mem` server configuration parameter to help speed up `CREATE INDEX` commands, though load performance is affected. Drop and recreate indexes only when there are no active users on the system.

- Create indexes last when loading data into new tables. Create the table, load the data, and create any required indexes.

- Run `ANALYZE` after loading data. If you significantly altered the data in a table, run `ANALYZE` or `VACUUM ANALYZE` to update table statistics for the query optimizer. Current statistics ensure that the optimizer makes the best decisions during query planning and avoids poor performance due to inaccurate or nonexistent statistics.

- Run `VACUUM` after load errors. If the load operation does not run in single row error isolation mode, the operation stops at the first error. The target table contains the rows loaded before the error occurred. You cannot access these rows, but they occupy disk space. Use the `VACUUM` command to recover the wasted space.

Parent topic: Loading and Unloading Data

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4.9.9 Unloading Data from WarehousePG

A writable external table allows you to select rows from other database tables and output the rows to files, named pipes, to applications. You can define file-based and web-based writable external tables.

This topic describes how to unload data from WarehousePG using parallel unload (writable external tables) and non-parallel unload (`COPY`).

- Defining a File-Based Writable External Table
- Defining a Command-Based Writable External Web Table
- Unloading Data Using a Writable External Table
- Unloading Data Using COPY

Parent topic: Loading and Unloading Data

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4.9.9.1 Defining a File-Based Writable External Table

Writable external tables that output data to files can use the WarehousePG parallel file server program, gpfdist, or the WarehousePG Platform Extension Framework (PXF), WarehousePG's interface to Hadoop.

Use the `CREATE WRITABLE EXTERNAL TABLE` command to define the external table and specify the location and format of the output files. See Using the WarehousePG Parallel File Server (gpfdist) for instructions on setting up gpfdist for use with an external table and Accessing External Data with PXF for instructions on setting up PXF for use with an external table

- With a writable external table using the gpfdist protocol, the WarehousePG segments send their data to gpfdist, which writes the data to the named file. gpfdist must run on a host that the WarehousePG segments can access over the network. gpfdist points to a file location on the output host and writes data received from the WarehousePG segments to the file. To divide the output data among multiple files, list multiple gpfdist URIs in your writable external table definition.
- A writable external web table sends data to an application as a stream of data. For example, unload data from WarehousePG and send it to an application that connects to another database or ETL tool to load the data elsewhere. Writable external web tables use the `EXECUTE` clause to specify a shell command, script, or application to run on the segment hosts and accept an input stream of data. See Defining a Command-Based Writable External Web Table for more information about using `EXECUTE` commands in a writable external table definition.

You can optionally declare a distribution policy for your writable external tables. By default, writable external tables use a random distribution policy. If the source table you are exporting data from has a hash distribution policy, defining the same distribution key column(s) for the writable external table improves unload performance by eliminating the requirement to move rows over the interconnect. If you unload data from a particular table, you can use the `LIKE` clause to copy the column definitions and distribution policy from the source table.

- **Example 1—WarehousePG file server (gpfdist)**
- **Example 2—Hadoop file server (pxf)**

Parent topic: Unloading Data from WarehousePG

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4.9.9.1.1 Example 1—WarehousePG file server (gpfdist)

```
=# CREATE WRITABLE EXTERNAL TABLE unload_expenses
   ( LIKE expenses )
   LOCATION ('gpfdist://etlhost-1:8081/expenses1.out',
             'gpfdist://etlhost-2:8081/expenses2.out')
 FORMAT 'TEXT' (DELIMITER ',')
 DISTRIBUTED BY (exp_id);
```

Parent topic: Defining a File-Based Writable External Table

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4.9.9.1.2 Example 2—Hadoop file server (pxf)

```
=# CREATE WRITABLE EXTERNAL TABLE unload_expenses
   ( LIKE expenses )
   LOCATION ('pxf://dir/path?PROFILE=hdfs:text')
 FORMAT 'TEXT' (DELIMITER ',')
 DISTRIBUTED BY (exp_id);
```

You specify an HDFS directory for a writable external table that you create with the `pxf` protocol.

Parent topic: Defining a File-Based Writable External Table

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4.9.9.2 Defining a Command-Based Writable External Web Table

You can define writable external web tables to send output rows to an application or script. The application must accept an input stream, reside in the same location on all of the WarehousePG segment hosts, and be executable by the `gpadmin` user. All segments in the WarehousePG cluster run the application or script, whether or not a segment has output rows to process.

Use `CREATE WRITABLE EXTERNAL WEB TABLE` to define the external table and specify the application or script to run on the segment hosts. Commands run from within the database and cannot access environment variables (such as `$PATH`). Set environment variables in the `EXECUTE` clause of your writable external table definition. For example:

```
=# CREATE WRITABLE EXTERNAL WEB TABLE output (output text)
    EXECUTE 'export PATH=$PATH:/home/`gpadmin`
            /programs;
    myprogram.sh'
    FORMAT 'TEXT'
    DISTRIBUTED RANDOMLY;
```

The following WarehousePG variables are available for use in OS commands run by a web or writable external table. Set these variables as environment variables in the shell that runs the command(s). They can be used to identify a set of requests made by an external table statement across the WarehousePG cluster of hosts and segment instances.

Variable	Description
$GP_CID	Command count of the transaction running the external table statement.
$GP_DATABASE	The database in which the external table definition resides.
$GP_DATE	The date on which the external table command ran.
$GP_COORDINATOR_HOST	The host name of the WarehousePG coordinator host from which the external table statement was dispatched.
$GP_COORDINATOR_PORT	The port number of the WarehousePG coordinator instance from which the external table statement was dispatched.
$GP_QUERY_STRING	The SQL command (DML or SQL query) run by WarehousePG.
$GP_SEG_DATADIR	The location of the data directory of the segment instance running the external table command.
$GP_SEG_PG_CONF	The location of the `postgresql.conf` file of the segment instance running the external table command.
$GP_SEG_PORT	The port number of the segment instance running the external table command.
$GP_SEGMENT_COUNT	The total number of primary segment instances in the WarehousePG cluster.
$GP_SEGMENT_ID	The ID number of the segment instance running the external table command (same as `content` in `gp_segment_configuration`).
$GP_SESSION_ID	The database session identifier number associated with the external table statement.
$GP_SN	Serial number of the external table scan node in the query plan of the external table statement.
$GP_TIME	The time the external table command was run.
$GP_USER	The database user running the external table statement.
$GP_XID	The transaction ID of the external table statement.

- Deactivating EXECUTE for Web or Writable External Tables

Parent topic: Unloading Data from WarehousePG

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4.9.9.2.1 Deactivating EXECUTE for Web or Writable External Tables

There is a security risk associated with allowing external tables to run OS commands or scripts. To deactivate the use of `EXECUTE` in web and writable external table definitions, set the `gp_external_enable_exec` server configuration parameter to off in your coordinator postgresql.conf file:

```
gp_external_enable_exec = off
```

> **Note** You must restart the database in order for changes to the `gp_external_enable_exec` server configuration parameter to take effect.

Parent topic: Defining a Command-Based Writable External Web Table

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4.9.9.3 Unloading Data Using a Writable External Table

Writable external tables allow only `INSERT` operations. You must grant `INSERT` permission on a table to enable access to users who are not the table owner or a superuser. For example:

```
GRANT INSERT ON writable_ext_table TO admin;
```

To unload data using a writable external table, select the data from the source table(s) and insert it into the writable external table. The resulting rows are output to the writable external table. For example:

```
INSERT INTO writable_ext_table SELECT * FROM regular_table;
```

Parent topic: Unloading Data from WarehousePG

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4.9.9.4 Unloading Data Using COPY

`COPY TO` copies data from a table to a file (or standard input) on the WarehousePG coordinator host using a single process on the WarehousePG coordinator instance. Use `COPY` to output a table's entire contents, or filter the output using a `SELECT` statement. For example:

```
COPY (SELECT * FROM country WHERE country_name LIKE 'A%')
TO '/home/gpadmin/a_list_countries.out';
```

Parent topic: Unloading Data from WarehousePG

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4.9.10 Formatting Data Files

When you use the WarehousePG tools for loading and unloading data, you must specify how your data is formatted. `COPY`, `CREATE EXTERNAL TABLE`, and `gpload` have clauses that allow you to specify how your data is formatted. Data can be delimited text (`TEXT`) or comma separated values (`CSV`) format. External data must be formatted correctly to be read by WarehousePG. This topic explains the format of data files expected by WarehousePG.

- Formatting Rows
- Formatting Columns
- Representing NULL Values
- Escaping
- Character Encoding

Parent topic: Loading and Unloading Data

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4.9.10.1 Formatting Rows

WarehousePG expects rows of data to be separated by the `LF` character (Line feed, `0x0A`), `CR` (Carriage return, `0x0D`), or `CR` followed by `LF` (`CR+LF`, `0x0D 0x0A`). `LF` is the standard newline representation on UNIX or UNIX-like operating systems. Operating systems such as Windows or Mac OS X use `CR` or `CR+LF`. All of these representations of a newline are supported by WarehousePG as a row delimiter. For more information, see Importing and Exporting Fixed Width Data.

Parent topic: Formatting Data Files

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4.9.10.2 Formatting Columns

The default column or field delimiter is the horizontal `TAB` character (`0x09`) for text files and the comma character (`0x2C`) for CSV files. You can declare a single character delimiter using the `DELIMITER` clause of `COPY` , `CREATE EXTERNAL TABLE` or `gpload` when you define your data format. The delimiter character must appear between any two data value fields. Do not place a delimiter at the beginning or end of a row. For example, if the pipe character (|) is your delimiter:

```
data value 1|data value 2|data value 3
```

The following command shows the use of the pipe character as a column delimiter:

```
=# CREATE EXTERNAL TABLE ext_table (name text, date date)
LOCATION ('gpfdist://<hostname>/filename.txt)
FORMAT 'TEXT' (DELIMITER '|');
```

Parent topic: Formatting Data Files

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4.9.10.3 Representing NULL Values

`NULL` represents an unknown piece of data in a column or field. Within your data files you can designate a string to represent null values. The default string is `\N` (backslash-N) in `TEXT` mode, or an empty value with no quotations in `CSV` mode. You can also declare a different string using the `NULL` clause of `COPY`, `CREATE EXTERNAL TABLE` or `gpload` when defining your data format. For example, you can use an empty string if you do not want to distinguish nulls from empty strings. When using the WarehousePG loading tools, any data item that matches the designated null string is considered a null value.

Parent topic: Formatting Data Files

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4.9.10.4 Escaping

There are two reserved characters that have special meaning to WarehousePG:

- The designated delimiter character separates columns or fields in the data file.
- The newline character designates a new row in the data file.

If your data contains either of these characters, you must escape the character so that WarehousePG treats it as data and not as a field separator or new row. By default, the escape character is a \ (backslash) for text-formatted files and a double quote (") for csv-formatted files.

- **Escaping in Text Formatted Files**
- **Escaping in CSV Formatted Files**

Parent topic: Formatting Data Files

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4.9.10.4.1 Escaping in Text Formatted Files

By default, the escape character is a \ (backslash) for text-formatted files. You can declare a different escape character in the `ESCAPE` clause of `COPY`, `CREATE EXTERNAL TABLE` or `gpload`. If your escape character appears in your data, use it to escape itself.

For example, suppose you have a table with three columns and you want to load the following three fields:

- `backslash = \`
- `vertical bar = |`
- `exclamation point = !`

Your designated delimiter character is `|` (pipe character), and your designated escape character is `\` (backslash). The formatted row in your data file looks like this:

```
backslash = \\ | vertical bar = \| | exclamation point = !
```

Notice how the backslash character that is part of the data is escaped with another backslash character, and the pipe character that is part of the data is escaped with a backslash character.

You can use the escape character to escape octal and hexadecimal sequences. The escaped value is converted to the equivalent character when loaded into WarehousePG. For example, to load the ampersand character `&`), use the escape character to escape its equivalent hexadecimal (`\0x26`) or octal (`\046`) representation.

You can deactivate escaping in `TEXT` -formatted files using the `ESCAPE` clause of `COPY`, `CREATE EXTERNAL TABLE` or `gpload` as follows:

```
ESCAPE 'OFF'
```

This is useful for input data that contains many backslash characters, such as web log data.

Parent topic: Escaping

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4.9.10.4.2 Escaping in CSV Formatted Files

By default, the escape character is a `"` (double quote) for CSV-formatted files. If you want to use a different escape character, use the `ESCAPE` clause of `COPY`, `CREATE EXTERNAL TABLE` or `gpload` to declare a different escape character. In cases where your selected escape character is present in your data, you can use it to escape itself.

For example, suppose you have a table with three columns and you want to load the following three fields:

- `Free trip to A,B`
- `5.89`
- `Special rate "1.79"`

Your designated delimiter character is `,` (comma), and your designated escape character is `"` (double quote). The formatted row in your data file looks like this:

```
"Free trip to A,B","5.89","Special rate ""1.79"""
```

The data value with a comma character that is part of the data is enclosed in double quotes. The double quotes that are part of the data are escaped with a double quote even though the field value is enclosed in double quotes.

Embedding the entire field inside a set of double quotes guarantees preservation of leading and trailing whitespace characters:

```
"Free trip to A,B ","5.89 ","Special rate ""1.79"" "
```

> **Note** In CSV mode, all characters are significant. A quoted value surrounded by white space, or any characters other than `DELIMITER`, includes those characters. This can cause errors if you import data from a system that pads CSV lines with white space to some fixed width. In this case, preprocess the CSV file to remove the trailing white space before importing the data into WarehousePG.

Parent topic: Escaping

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4.9.10.5 Character Encoding

Character encoding systems consist of a code that pairs each character from a character set with something else, such as a sequence of numbers or octets, to facilitate data transmission and storage. WarehousePG supports a variety of character sets, including single-byte character sets such as the ISO 8859 series and multiple-byte character sets such as EUC (Extended UNIX Code), UTF-8, and Mule internal code. The server-side character set is defined during database initialization, UTF-8 is the default and can be changed. Clients can use all supported character sets transparently, but a few are not supported for use within the server as a server-side encoding. When loading or inserting data into WarehousePG, WarehousePG transparently converts the data from the specified client encoding into the server encoding. When sending data back to the client, WarehousePG converts the data from the server character encoding into the specified client encoding.

Data files must be in a character encoding recognized by WarehousePG. See the *WarehousePG Reference Guide* for the supported character sets.Data files that contain invalid or unsupported encoding sequences encounter errors when loading into WarehousePG.

> **Note** On data files generated on a Microsoft Windows operating system, run the `dos2unix` system command to remove any Windows-only characters before loading into WarehousePG.

> **Note** If you *change* the `ENCODING` value in an existing `gpload` control file, you must manually drop any external tables that were creating using the previous `ENCODING` configuration. `gpload` does not drop and recreate external tables to use the new `ENCODING` if `REUSE_TABLES` is set to `true`.

Parent topic: Formatting Data Files

Changing the Client-Side Character Encoding

The client-side character encoding can be changed for a session by setting the server configuration parameter `client_encoding`

```
SET client_encoding TO 'latin1';
```

Change the client-side character encoding back to the default value:

```
RESET client_encoding;
```

Show the current client-side character encoding setting:

```
SHOW client_encoding;
```

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4.9.11 Example Custom Data Access Protocol

The following is the API for the WarehousePG custom data access protocol. The example protocol implementation gpextprotocal.c is written in C and shows how the API can be used. For information about accessing a custom data access protocol, see Using a Custom Protocol.

```
/* ---- Read/Write function API ------*/
CALLED_AS_EXTPROTOCOL(fcinfo)
EXTPROTOCOL_GET_URL(fcinfo)(fcinfo)
EXTPROTOCOL_GET_DATABUF(fcinfo)
EXTPROTOCOL_GET_DATALEN(fcinfo)
EXTPROTOCOL_GET_SCANQUALS(fcinfo)
EXTPROTOCOL_GET_USER_CTX(fcinfo)
EXTPROTOCOL_IS_LAST_CALL(fcinfo)
EXTPROTOCOL_SET_LAST_CALL(fcinfo)
EXTPROTOCOL_SET_USER_CTX(fcinfo, p)

/* ------ Validator function API ------*/
CALLED_AS_EXTPROTOCOL_VALIDATOR(fcinfo)
EXTPROTOCOL_VALIDATOR_GET_URL_LIST(fcinfo)
EXTPROTOCOL_VALIDATOR_GET_NUM_URLS(fcinfo)
EXTPROTOCOL_VALIDATOR_GET_NTH_URL(fcinfo, n)
EXTPROTOCOL_VALIDATOR_GET_DIRECTION(fcinfo)
```

Notes

The protocol corresponds to the example described in Using a Custom Protocol. The source code file name and shared object are `gpextprotocol.c` and `gpextprotocol.so`.

The protocol has the following properties:

- The name defined for the protocol is `myprot`.
- The protocol has the following simple form: the protocol name and a path, separated by `://`.

  `myprot://` `path`
- Three functions are implemented:
  - `myprot_import()` a read function
  - `myprot_export()` a write function
  - `myprot_validate_urls()` a validation function These functions are referenced in the `CREATE PROTOCOL` statement when the protocol is created and declared in the database.

The example implementation gpextprotocal.c uses `fopen()` and `fread()` to simulate a simple protocol that reads local files. In practice, however, the protocol would implement functionality such as a remote connection to some process over the network.

- **Installing the External Table Protocol**

Parent topic: Loading and Unloading Data

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4.9.11.1 Installing the External Table Protocol

To use the example external table protocol, you use the C compiler `cc` to compile and link the source code to create a shared object that can be dynamically loaded by WarehousePG. The commands to compile and link the source code on a Linux system are similar to this:

```
cc -fpic -c gpextprotocal.c cc -shared -o gpextprotocal.so gpextprotocal.o
```

The option `-fpic` specifies creating position-independent code (PIC) and the `-c` option compiles the source code without linking and creates an object file. The object file needs to be created as position-independent code (PIC) so that it can be loaded at any arbitrary location in memory by WarehousePG.

The flag `-shared` specifies creating a shared object (shared library) and the `-o` option specifies the shared object file name `gpextprotocal.so`. Refer to the GCC manual for more information on the `cc` options.

The header files that are declared as include files in `gpextprotocal.c` are located in subdirectories of `$GPHOME/include/postgresql/.`

For more information on compiling and linking dynamically-loaded functions and examples of compiling C source code to create a shared library on other operating systems, see the PostgreSQL documentation at https://www.postgresql.org/docs/12/xfunc-c.html#DFUNC.

The manual pages for the C compiler `cc` and the link editor `ld` for your operating system also contain information on compiling and linking source code on your system.

The compiled code (shared object file) for the custom protocol must be placed in the same location on every host in your WarehousePG cluster (coordinator and all segments). This location must also be in the `LD_LIBRARY_PATH` so that the server can locate the files. It is recommended to locate shared libraries either relative to `$libdir` (which is located at `$GPHOME/lib`) or through the dynamic library path (set by the `dynamic_library_path` server configuration parameter) on all coordinator segment instances in the WarehousePG cluster. You can use the WarehousePG utilities gpssh and `gpsync` to update segments.

- **gpextprotocal.c**

Parent topic: Example Custom Data Access Protocol

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4.9.11.1.1 gpextprotocal.c

```
#include "postgres.h"
#include "fmgr.h"
#include "funcapi.h"
#include "access/extprotocol.h"
#include "catalog/pg_proc.h"
#include "utils/array.h"
#include "utils/builtins.h"
#include "utils/memutils.h"

/* Our chosen URI format. We can change it however needed */
typedef struct DemoUri
{
   char     *protocol;
   char     *path;
}  DemoUri;
static DemoUri *ParseDemoUri(const char *uri_str);
static void FreeDemoUri(DemoUri* uri);

/* Do the module magic dance */
PG_MODULE_MAGIC;
PG_FUNCTION_INFO_V1(demoprot_export);
PG_FUNCTION_INFO_V1(demoprot_import);
PG_FUNCTION_INFO_V1(demoprot_validate_urls);

Datum demoprot_export(PG_FUNCTION_ARGS);
Datum demoprot_import(PG_FUNCTION_ARGS);
Datum demoprot_validate_urls(PG_FUNCTION_ARGS);

/* A user context that persists across calls. Can be
declared in any other way */
typedef struct {
  char    *url;
  char    *filename;
  FILE    *file;
} extprotocol_t;
/*
* The read function - Import data into GPDB.
*/
Datum
myprot_import(PG_FUNCTION_ARGS)
{
  extprotocol_t   *myData;
  char            *data;
  int             datlen;
  size_t          nread = 0;

  /* Must be called via the external table format manager */
  if (!CALLED_AS_EXTPROTOCOL(fcinfo))
    elog(ERROR, "myprot_import: not called by external
       protocol manager");

  /* Get our internal description of the protocol */
  myData = (extprotocol_t *) EXTPROTOCOL_GET_USER_CTX(fcinfo);

  if(EXTPROTOCOL_IS_LAST_CALL(fcinfo))
  {
    /* we're done receiving data. close our connection */
    if(myData && myData->file)
      if(fclose(myData->file))
        ereport(ERROR,
          (errcode_for_file_access(),
           errmsg("could not close file \"%s\": %m",
               myData->filename)));

    PG_RETURN_INT32(0);
  }

  if (myData == NULL)
  {
    /* first call. do any desired init */

    const char    *p_name = "myprot";
    DemoUri       *parsed_url;
    char          *url = EXTPROTOCOL_GET_URL(fcinfo);
    myData        = palloc(sizeof(extprotocol_t));

    myData->url   = pstrdup(url);
    parsed_url    = ParseDemoUri(myData->url);
    myData->filename = pstrdup(parsed_url->path);

    if(strcasecmp(parsed_url->protocol, p_name) != 0)
      elog(ERROR, "internal error: myprot called with a
          different protocol (%s)",
            parsed_url->protocol);

    FreeDemoUri(parsed_url);

    /* open the destination file (or connect to remote server in
       other cases) */
```

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```
    myData->file = fopen(myData->filename, "r");

    if (myData->file == NULL)
      ereport(ERROR,
          (errcode_for_file_access(),
           errmsg("myprot_import: could not open file \"%s\"
             for reading: %m",
             myData->filename),
           errOmitLocation(true)));

    EXTPROTOCOL_SET_USER_CTX(fcinfo, myData);
  }
  /* ========================================
   *          DO THE IMPORT
   * ======================================== */
  data    = EXTPROTOCOL_GET_DATABUF(fcinfo);
  datlen  = EXTPROTOCOL_GET_DATALEN(fcinfo);

  /* read some bytes (with fread in this example, but normally
     in some other method over the network) */
  if(datlen > 0)
  {
    nread = fread(data, 1, datlen, myData->file);
    if (ferror(myData->file))
      ereport(ERROR,
        (errcode_for_file_access(),
          errmsg("myprot_import: could not write to file
            \"%s\": %m",
            myData->filename)));
  }
  PG_RETURN_INT32((int)nread);
}
/*
 * Write function - Export data out of GPDB
 */
Datum
myprot_export(PG_FUNCTION_ARGS)
{
  extprotocol_t  *myData;
  char           *data;
  int            datlen;
  size_t         wrote = 0;

  /* Must be called via the external table format manager */
  if (!CALLED_AS_EXTPROTOCOL(fcinfo))
    elog(ERROR, "myprot_export: not called by external
       protocol manager");

  /* Get our internal description of the protocol */
  myData = (extprotocol_t *) EXTPROTOCOL_GET_USER_CTX(fcinfo);
  if(EXTPROTOCOL_IS_LAST_CALL(fcinfo))
  {
    /* we're done sending data. close our connection */
    if(myData && myData->file)
      if(fclose(myData->file))
        ereport(ERROR,
            (errcode_for_file_access(),
              errmsg("could not close file \"%s\": %m",
                 myData->filename)));

    PG_RETURN_INT32(0);
  }
  if (myData == NULL)
  {
    /* first call. do any desired init */
    const char *p_name = "myprot";
    DemoUri    *parsed_url;
    char       *url = EXTPROTOCOL_GET_URL(fcinfo);

    myData           = palloc(sizeof(extprotocol_t));

    myData->url      = pstrdup(url);
    parsed_url       = ParseDemoUri(myData->url);
    myData->filename = pstrdup(parsed_url->path);

    if(strcasecmp(parsed_url->protocol, p_name) != 0)
      elog(ERROR, "internal error: myprot called with a
         different protocol (%s)",
         parsed_url->protocol);

    FreeDemoUri(parsed_url);

    /* open the destination file (or connect to remote server in
    other cases) */
    myData->file = fopen(myData->filename, "a");
    if (myData->file == NULL)
      ereport(ERROR,
        (errcode_for_file_access(),
           errmsg("myprot_export: could not open file \"%s\"
             for writing: %m",
             myData->filename),
         errOmitLocation(true)));
```

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```
    EXTPROTOCOL_SET_USER_CTX(fcinfo, myData);
  }
  /* ========================================
   *      DO THE EXPORT
   * ======================================== */
  data   = EXTPROTOCOL_GET_DATABUF(fcinfo);
  datlen   = EXTPROTOCOL_GET_DATALEN(fcinfo);

  if(datlen > 0)
  {
    wrote = fwrite(data, 1, datlen, myData->file);

    if (ferror(myData->file))
      ereport(ERROR,
        (errcode_for_file_access(),
         errmsg("myprot_import: could not read from file
            \"%s\": %m",
            myData->filename)));
  }
  PG_RETURN_INT32((int)wrote);
}
Datum
myprot_validate_urls(PG_FUNCTION_ARGS)
{
  List         *urls;
  int          nurls;
  int          i;
  ValidatorDirection  direction;

  /* Must be called via the external table format manager */
  if (!CALLED_AS_EXTPROTOCOL_VALIDATOR(fcinfo))
    elog(ERROR, "myprot_validate_urls: not called by external
       protocol manager");

  nurls       = EXTPROTOCOL_VALIDATOR_GET_NUM_URLS(fcinfo);
  urls        = EXTPROTOCOL_VALIDATOR_GET_URL_LIST(fcinfo);
  direction   = EXTPROTOCOL_VALIDATOR_GET_DIRECTION(fcinfo);
  /*
   * Dumb example 1: search each url for a substring
   * we don't want to be used in a url. in this example
   * it's 'secured_directory'.
   */
  for (i = 1 ; i <= nurls ; i++)
  {
    char *url = EXTPROTOCOL_VALIDATOR_GET_NTH_URL(fcinfo, i);

    if (strstr(url, "secured_directory") != 0)
    {
      ereport(ERROR,
       (errcode(ERRCODE_PROTOCOL_VIOLATION),
          errmsg("using 'secured_directory' in a url
            isn't allowed ")));
    }
  }
  /*
   * Dumb example 2: set a limit on the number of urls
   * used. In this example we limit readable external
   * tables that use our protocol to 2 urls max.
   */
  if(direction == EXT_VALIDATE_READ && nurls > 2)
  {
    ereport(ERROR,
      (errcode(ERRCODE_PROTOCOL_VIOLATION),
        errmsg("more than 2 urls aren't allowed in this protocol ")));
  }
  PG_RETURN_VOID();
}
/* --- utility functions --- */
static
DemoUri *ParseDemoUri(const char *uri_str)
{
  DemoUri *uri = (DemoUri *) palloc0(sizeof(DemoUri));
  int     protocol_len;

   uri->path = NULL;
   uri->protocol = NULL;
  /*
   * parse protocol
   */
  char *post_protocol = strstr(uri_str, "://");

  if(!post_protocol)
  {
    ereport(ERROR,
      (errcode(ERRCODE_SYNTAX_ERROR),
       errmsg("invalid protocol URI \'%s\'", uri_str),
       errOmitLocation(true)));
  }

  protocol_len = post_protocol - uri_str;
  uri->protocol = (char *)palloc0(protocol_len + 1);
  strncpy(uri->protocol, uri_str, protocol_len);
```

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```
  /* make sure there is more to the uri string */
  if (strlen(uri_str) <= protocol_len)
    ereport(ERROR,
      (errcode(ERRCODE_SYNTAX_ERROR),
       errmsg("invalid myprot URI \'%s\' : missing path",
         uri_str),
      errOmitLocation(true)));

  /* parse path */
  uri->path = pstrdup(uri_str + protocol_len + strlen("://"));

  return uri;
}
static
void FreeDemoUri(DemoUri *uri)
{
  if (uri->path)
    pfree(uri->path);
  if (uri->protocol)
    pfree(uri->protocol);

  pfree(uri);
}
```

Parent topic: Installing the External Table Protocol

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4.10 Managing Performance

The topics in this section cover WarehousePG performance management, including how to monitor performance and how to configure workloads to prioritize resource utilization.

- Defining Database Performance
  Managing system performance includes measuring performance, identifying the causes of performance problems, and applying the tools and techniques available to you to remedy the problems.
- Common Causes of Performance Issues
  This section explains the troubleshooting processes for common performance issues and potential solutions to these issues.
- WarehousePG Memory Overview
  Memory is a key resource for a WarehousePG cluster and, when used efficiently, can ensure high performance and throughput. This topic describes how segment host memory is allocated between segments and the options available to administrators to configure memory.
- Managing Resources
  WarehousePG provides features to help you prioritize and allocate resources to queries according to business requirements and to prevent queries from starting when resources are unavailable.
- Investigating a Performance Problem
  This section provides guidelines for identifying and troubleshooting performance problems in a WarehousePG cluster.

Parent topic: WarehousePG Administrator Guide

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4.10.1 Defining Database Performance

Managing system performance includes measuring performance, identifying the causes of performance problems, and applying the tools and techniques available to you to remedy the problems.

WarehousePG measures database performance based on the rate at which the database management system (DBMS) supplies information to requesters.

Parent topic: Managing Performance

Understanding the Performance Factors

Several key performance factors influence database performance. Understanding these factors helps identify performance opportunities and avoid problems:

- System Resources
- Workload
- Throughput
- Contention
- Optimization

System Resources

Database performance relies heavily on disk I/O and memory usage. To accurately set performance expectations, you need to know the baseline performance of the hardware on which your DBMS is deployed. Performance of hardware components such as CPUs, hard disks, disk controllers, RAM, and network interfaces will significantly affect how fast your database performs.

> **Note** If you use endpoint security software on your WarehousePG hosts, it may affect your database performance and stability. SeeAbout Endpoint Security Sofware for more information.

Workload

The workload equals the total demand from the DBMS, and it varies over time. The total workload is a combination of user queries, applications, batch jobs, transactions, and system commands directed through the DBMS at any given time. For example, it can increase when month-end reports are run or decrease on weekends when most users are out of the office. Workload strongly influences database performance. Knowing your workload and peak demand times helps you plan for the most efficient use of your system resources and enables processing the largest possible workload.

Throughput

A system's throughput defines its overall capability to process data. DBMS throughput is measured in queries per second, transactions per second, or average response times. DBMS throughput is closely related to the processing capacity of the underlying systems (disk I/O, CPU speed, memory bandwidth, and so on), so it is important to know the throughput capacity of your hardware when setting DBMS throughput goals.

Contention

Contention is the condition in which two or more components of the workload attempt to use the system in a conflicting way — for example, multiple queries that try to update the same piece of data at the same time or multiple large workloads that compete for system resources. As contention increases, throughput decreases.

Optimization

DBMS optimizations can affect the overall system performance. SQL formulation, database configuration parameters, table design, data distribution, and so on enable the database query optimizer to create the most efficient access plans.

Determining Acceptable Performance

When approaching a performance tuning initiative, you should know your system's expected level of performance and define measurable performance requirements so you can accurately evaluate your system's performance. Consider the following when setting performance goals:

- Baseline Hardware Performance
- Performance Benchmarks

Baseline Hardware Performance

Most database performance problems are caused not by the database, but by the underlying systems on which the database runs. I/O bottlenecks, memory problems, and network issues can notably degrade database performance. Knowing the baseline capabilities of your hardware and operating system (OS) will help you identify and troubleshoot hardware-related problems before you explore database-level or query-level tuning initiatives.

See the *WarehousePG Reference Guide* for information about running the `gpcheckperf` utility to validate hardware and network performance.

Performance Benchmarks

To maintain good performance or fix performance issues, you should know the capabilities of your DBMS on a defined workload. A benchmark is a predefined workload that produces a known result set. Periodically run the same benchmark tests to help identify system-related performance degradation over time. Use benchmarks to compare workloads and identify queries or applications that need optimization.

Many third-party organizations, such as the Transaction Processing Performance Council (TPC), provide benchmark tools for the database industry. TPC provides TPC-H, a decision support system that examines large volumes of data, runs queries with a high degree of complexity, and gives answers to critical business questions. For more information about TPC-H, go to:

http://www.tpc.org/tpch

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4.10.2 Distribution and Skew

WarehousePG relies on even distribution of data across segments.

In an MPP shared nothing environment, overall response time for a query is measured by the completion time for all segments. The system is only as fast as the slowest segment. If the data is skewed, segments with more data will take more time to complete, so every segment must have an approximately equal number of rows and perform approximately the same amount of processing. Poor performance and out of memory conditions may result if one segment has significantly more data to process than other segments.

Optimal distributions are critical when joining large tables together. To perform a join, matching rows must be located together on the same segment. If data is not distributed on the same join column, the rows needed from one of the tables are dynamically redistributed to the other segments. In some cases a broadcast motion, in which each segment sends its individual rows to all other segments, is performed rather than a redistribution motion, where each segment rehashes the data and sends the rows to the appropriate segments according to the hash key.

Parent topic: WarehousePG Administrator Guide

Local (Co-located) Joins

Using a hash distribution that evenly distributes table rows across all segments and results in local joins can provide substantial performance gains. When joined rows are on the same segment, much of the processing can be accomplished within the segment instance. These are called *local* or *co-located* joins. Local joins minimize data movement; each segment operates independently of the other segments, without network traffic or communications between segments.

To achieve local joins for large tables commonly joined together, distribute the tables on the same column. Local joins require that both sides of a join be distributed on the same columns (and in the same order) *and* that all columns in the distribution clause are used when joining tables. The distribution columns must also be the same data type—although some values with different data types may appear to have the same representation, they are stored differently and hash to different values, so they are stored on different segments.

Data Skew

Data skew may be caused by uneven data distribution due to the wrong choice of distribution keys or single tuple table insert or copy operations. Present at the table level, data skew, is often the root cause of poor query performance and out of memory conditions. Skewed data affects scan (read) performance, but it also affects all other query execution operations, for instance, joins and group by operations.

It is very important to *validate* distributions to *ensure* that data is evenly distributed after the initial load. It is equally important to *continue* to validate distributions after incremental loads.

The following query shows the number of rows per segment as well as the variance from the minimum and maximum numbers of rows:

```
SELECT 'Example Table' AS "Table Name",
    max(c) AS "Max Seg Rows", min(c) AS "Min Seg Rows",
    (max(c)-min(c))*100.0/max(c) AS "Percentage Difference Between Max & Min"
FROM (SELECT count(*) c, gp_segment_id FROM facts GROUP BY 2) AS a;
```

The `gp_toolkit` schema has two views that you can use to check for skew.

- The `gp_toolkit.gp_skew_coefficients` view shows data distribution skew by calculating the coefficient of variation (CV) for the data stored on each segment. The `skccoeff` column shows the coefficient of variation (CV), which is calculated as the standard deviation divided by the average. It takes into account both the average and variability around the average of a data series. The lower the value, the better. Higher values indicate greater data skew.
- The `gp_toolkit.gp_skew_idle_fractions` view shows data distribution skew by calculating the percentage of the system that is idle during a table scan, which is an indicator of computational skew. The `siffraction` column shows the percentage of the system that is idle during a table scan. This is an indicator of uneven data distribution or query processing skew. For example, a value of 0.1 indicates 10% skew, a value of 0.5 indicates 50% skew, and so on. Tables that have more than10% skew should have their distribution policies evaluated.

Considerations for Replicated Tables

When you create a replicated table (with the `CREATE TABLE` clause `DISTRIBUTED REPLICATED`), WarehousePG distributes every table row to every segment instance. Replicated table data is evenly distributed because every segment has the same rows. A query that uses the `gp_segment_id` system column on a replicated table to verify evenly distributed data, will fail because WarehousePG does not allow queries to reference replicated tables' system columns.

Processing Skew

Processing skew results when a disproportionate amount of data flows to, and is processed by, one or a few segments. It is often the culprit behind WarehousePG performance and stability issues. It can happen with operations such join, sort, aggregation, and various OLAP operations. Processing skew happens in flight while a query is running and is not as easy to detect as data skew.

If single segments are failing, that is, not all segments on a host, it may be a processing skew issue. Identifying processing skew is currently a manual process. First look for spill files. If there is skew, but not enough to cause spill, it will not become a performance issue. If you determine skew exists, then find the query responsible for the skew.

The remedy for processing skew in almost all cases is to rewrite the query. Creating temporary tables can eliminate skew. Temporary tables can be randomly distributed to force a two-stage aggregation.

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4.10.3 Common Causes of Performance Issues

This section explains the troubleshooting processes for common performance issues and potential solutions to these issues.

Parent topic: Managing Performance

Identifying Hardware and Segment Failures

The performance of WarehousePG depends on the hardware and IT infrastructure on which it runs. WarehousePG is comprised of several servers (hosts) acting together as one cohesive system (array); as a first step in diagnosing performance problems, ensure that all WarehousePG segments are online. WarehousePG's performance will be as fast as the slowest host in the array. Problems with CPU utilization, memory management, I/O processing, or network load affect performance. Common hardware-related issues are:

- **Disk Failure** – Although a single disk failure should not dramatically affect database performance if you are using RAID, disk resynchronization does consume resources on the host with failed disks. The `gpcheckperf` utility can help identify segment hosts that have disk I/O issues.
- **Host Failure** – When a host is offline, the segments on that host are nonoperational. This means other hosts in the array must perform twice their usual workload because they are running the primary segments and multiple mirrors. If mirrors are not enabled, service is interrupted. Service is temporarily interrupted to recover failed segments. The `gpstate` utility helps identify failed segments.
- **Network Failure** – Failure of a network interface card, a switch, or DNS server can bring down segments. If host names or IP addresses cannot be resolved within your WarehousePG cluster, these manifest themselves as interconnect errors in WarehousePG. The `gpcheckperf` utility helps identify segment hosts that have network issues.
- **Disk Capacity** – Disk capacity on your segment hosts should never exceed 70 percent full. WarehousePG needs some free space for runtime processing. To reclaim disk space that deleted rows occupy, run `VACUUM` after loads or updates.The *gp_toolkit* administrative schema has many views for checking the size of distributed database objects.

  See the *WarehousePG Reference Guide* for information about checking database object sizes and disk space.

Managing Workload

A database system has a limited CPU capacity, memory, and disk I/O resources. When multiple workloads compete for access to these resources, database performance degrades. Resource management maximizes system throughput while meeting varied business requirements. WarehousePG provides resource queues and resource groups to help you manage these system resources.

Resource queues and resource groups limit resource usage and the total number of concurrent queries running in the particular queue or group. By assigning database roles to the appropriate queue or group, administrators can control concurrent user queries and prevent system overload. For more information about resource queues and resource groups, including selecting the appropriate scheme for your WarehousePG environment, see Managing Resources.

WarehousePG administrators should run maintenance workloads such as data loads and `VACUUM ANALYZE` operations after business hours. Do not compete with database users for system resources; perform administrative tasks at low-usage times.

Avoiding Contention

Contention arises when multiple users or workloads try to use the system in a conflicting way; for example, contention occurs when two transactions try to update a table simultaneously. A transaction that seeks a table-level or row-level lock will wait indefinitely for conflicting locks to be released. Applications should not hold transactions open for long periods of time, for example, while waiting for user input.

Maintaining Database Statistics

WarehousePG uses a cost-based query optimizer that relies on database statistics. Accurate statistics allow the query optimizer to better estimate the number of rows retrieved by a query to choose the most efficient query plan. Without database statistics, the query optimizer cannot estimate how many records will be returned. The optimizer does not assume it has sufficient memory to perform certain operations such as aggregations, so it takes the most conservative action and does these operations by reading and writing from disk. This is significantly slower than doing them in memory. ANALYZE collects statistics about the database that the query optimizer needs.

> **Note** When running an SQL command with GPORCA, WarehousePG issues a warning if the command performance could be improved by collecting statistics on a column or set of columns referenced by the command. The warning is issued on the command line and information is added to the WarehousePG log file. For information about collecting statistics on table columns, see the ANALYZE command in the *WarehousePG Reference Guide*

Identifying Statistics Problems in Query Plans

Before you interpret a query plan for a query using EXPLAIN or `EXPLAIN ANALYZE`, familiarize yourself with the data to help identify possible statistics problems. Check the plan for the following indicators of inaccurate statistics:

- **Are the optimizer's estimates close to reality?** Run `EXPLAIN ANALYZE` and see if the number of rows the optimizer estimated is close to the number of rows the query operation returned.
- **Are selective predicates applied early in the plan?** The most selective filters should be applied early in the plan so fewer rows move up the plan tree.
- **Is the optimizer choosing the best join order?** When you have a query that joins multiple tables, make sure the optimizer chooses the most selective join order. Joins that eliminate the largest number of rows should be done earlier in the plan so fewer rows move up the plan tree.

See Query Profiling for more information about reading query plans.

Tuning Statistics Collection

The following configuration parameters control the amount of data sampled for statistics collection:

- `default_statistics_target`

These parameters control statistics sampling at the system level. It is better to sample only increased statistics for columns used most frequently in query predicates. You can adjust statistics for a particular column using the command:

`ALTER TABLE...SET STATISTICS`

For example:

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```
ALTER TABLE sales ALTER COLUMN region SET STATISTICS 50;
```

This is equivalent to changing `default_statistics_target` for a particular column. Subsequent `ANALYZE` operations will then gather more statistics data for that column and produce better query plans as a result.

Optimizing Data Distribution

When you create a table in WarehousePG, you must declare a distribution key that allows for even data distribution across all segments in the system. Because the segments work on a query in parallel, WarehousePG will always be as fast as the slowest segment. If the data is unbalanced, the segments that have more data will return their results slower and therefore slow down the entire system.

Optimizing Your Database Design

Many performance issues can be improved by database design. Examine your database design and consider the following:

- Does the schema reflect the way the data is accessed?
- Can larger tables be broken down into partitions?
- Are you using the smallest data type possible to store column values?
- Are columns used to join tables of the same datatype?
- Are your indexes being used?

WarehousePG Maximum Limits

To help optimize database design, review the maximum limits that WarehousePG supports:

Dimension	Limit
Database Size	Unlimited
Table Size	Unlimited, 128 TB per partition per segment
Row Size	1.6 TB (1600 columns * 1 GB)
Field Size	1 GB
Rows per Table	281474976710656 (2^48)
Columns per Table/View	1600
Indexes per Table	Unlimited
Columns per Index	32
Table-level Constraints per Table	Unlimited
Table Name Length	63 Bytes (Limited by *name* data type)

Dimensions listed as unlimited are not intrinsically limited by WarehousePG. However, they are limited in practice to available disk space and memory/swap space. Performance may degrade when these values are unusually large.

> **Note** There is a maximum limit on the number of objects (tables, indexes, and views, but not rows) that may exist at one time. This limit is 4294967296 (2^32).

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4.10.4 WarehousePG Memory Overview

Memory is a key resource for a WarehousePG cluster and, when used efficiently, can ensure high performance and throughput. This topic describes how segment host memory is allocated between segments and the options available to administrators to configure memory.

A WarehousePG segment host runs multiple PostgreSQL instances, all sharing the host's memory. The segments have an identical configuration and they consume similar amounts of memory, CPU, and disk IO simultaneously, while working on queries in parallel.

For best query throughput, the memory configuration should be managed carefully. There are memory configuration options at every level in WarehousePG, from operating system parameters, to managing resources with resource queues and resource groups, to setting the amount of memory allocated to an individual query.

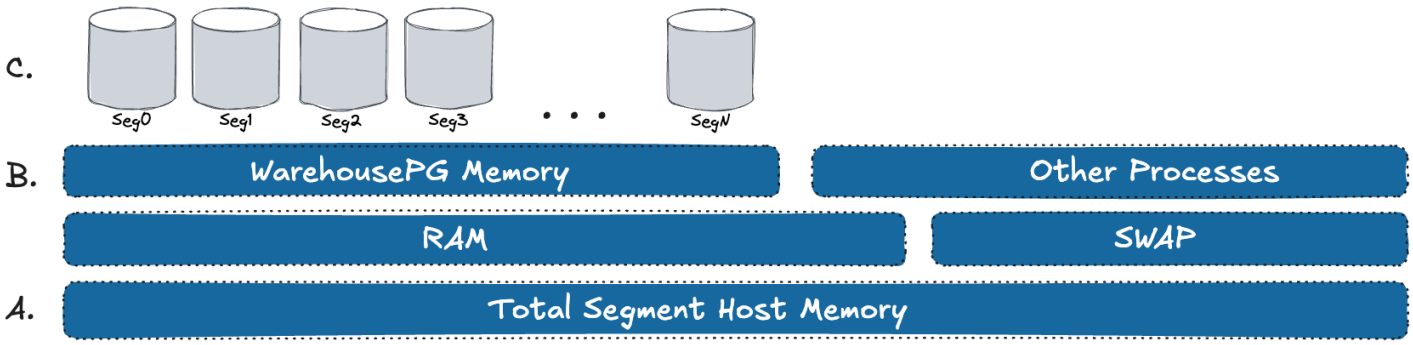
Memory calculator tool

For an automated way to determine the required values based on your specific hardware, use the WarehousePG memory calculator. Input your system's RAM, swap, and segment count to get the optimized `gp_vmem_protect_limit` and `vm.overcommit_ratio` values.

Segment Host Memory Overview

On a WarehousePG segment host, the available host memory is shared among all the processes running on the computer, including the operating system, WarehousePG segment instances, and other application processes. Administrators must determine what WarehousePG and non-WarehousePG processes share the hosts' memory and configure the system to use the memory efficiently. It is equally important to monitor memory usage regularly to detect any changes in the way host memory is consumed by WarehousePG or other processes.

The following figure illustrates how memory is consumed on a WarehousePG segment host when resource queue-based resource management is active.



Beginning at the bottom of the illustration, the line labeled *A* represents the total host memory. The line directly above line *A* shows that the total host memory comprises both physical RAM and swap space.

The line labelled *B* shows that the total memory available must be shared by WarehousePG and all other processes on the host. Non-WarehousePG processes include the operating system and any other applications, for example system monitoring agents. Some applications may use a significant portion of memory and, as a result, you may have to adjust the number of segments per WarehousePG host or the amount of memory per segment.

Each segment on line labelled *C* gets an equal share of the WarehousePG Memory.

Within a segment, the currently active resource management scheme, Resource Queues or Resource Groups, governs how memory is allocated to run a SQL statement. These constructs allow you to translate business requirements into execution policies in your WarehousePG cluster and to guard against queries that could degrade performance. For an overview of resource groups and resource queues, refer to Managing Resources.

Configuring Segment Host Memory

Host memory is the total memory shared by all applications on the segment host. You can configure the amount of host memory using any of the following methods:

- Add more RAM to the nodes to increase the physical memory.
- Allocate swap space to increase the size of virtual memory.
- Adjust the kernel parameter `vm.overcommit_ratio` to configure how the operating system handles large memory allocation requests.

The physical RAM and OS configuration are usually managed by the platform team and system administrators. See the WarehousePG Installation Guide for the recommended kernel parameters and for how to set the `/etc/sysctl.conf` file parameters.

The amount of memory to reserve for the operating system and other processes is workload dependent. The minimum recommendation for operating system memory is 32GB, but if there is much concurrency in WarehousePG, increasing to 64GB of reserved memory may be required. The largest user of operating system memory is SLAB, which increases as WarehousePG concurrency and the number of sockets used increases.

The `vm.overcommit_memory` kernel parameter should always be set to 2, the only safe value for WarehousePG.

The `vm.overcommit_ratio` kernel parameter sets the percentage of RAM that is used for application processes, the remainder reserved for the operating system. The default for Red Hat is 50 (50%). Setting this parameter too high may result in insufficient memory reserved for the operating system, which can cause segment host failure or database failure. Leaving the setting at the default of 50 is generally safe, but conservative. Setting the value too low reduces the amount of concurrency and the complexity of queries you can run at the same time by reducing the amount of memory available to WarehousePG. When increasing `vm.overcommit_ratio`, it is important to remember to always reserve some memory for operating system activities.

To calculate a safe value for `vm.overcommit_ratio`, first determine the total memory available to WarehousePG processes, `gp_vmem`.

- If the total system memory is less than 256 GB, use this formula:

```
gp_vmem = ((SWAP + RAM) – (7.5GB + 0.05 * RAM)) / 1.7
```

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- If the total system memory is equal to or greater than 256 GB, use this formula:

```
gp_vmem = ((SWAP + RAM) – (7.5GB + 0.05 * RAM)) / 1.17
```

where `SWAP` is the swap space on the host in GB, and `RAM` is the number of GB of RAM installed on the host.

Use `gp_vmem` to calculate the `vm.overcommit_ratio` value with this formula:

```
vm.overcommit_ratio = (RAM – 0.026 * gp_vmem) / RAM
```

Configuring WarehousePG Memory

WarehousePG Memory is the amount of memory available to all WarehousePG segment instances.

When you set up the WarehousePG cluster, you determine the number of primary segments to run per host and the amount of memory to allocate for each segment. Depending on the CPU cores, amount of physical RAM, and workload characteristics, the number of segments is usually a value between 4 and 8. With segment mirroring enabled, it is important to allocate memory for the maximum number of primary segments running on a host during a failure. For example, if you use the default grouping mirror configuration, a segment host failure doubles the number of acting primaries on the host that has the failed host's mirrors. Mirror configurations that spread each host's mirrors over multiple other hosts can lower the maximum, allowing more memory to be allocated for each segment. For example, if you use a block mirroring configuration with 4 hosts per block and 8 primary segments per host, a single host failure would cause other hosts in the block to have a maximum of 11 active primaries, compared to 16 for the default grouping mirror configuration.

The gp_vmem_protect_limit server configuration parameter value identifies the amount of memory to allocate to each segment. This value is estimated by calculating the memory available for all WarehousePG processes and dividing by the maximum number of primary segments during a failure. If `gp_vmem_protect_limit` is set too high, queries can fail. Use the following formula to calculate a safe value for `gp_vmem_protect_limit`, using the `gp_vmem` value that you calculated earlier.

```
gp_vmem_protect_limit = gp_vmem / max_acting_primary_segments
```

where `max_acting_primary_segments` is the maximum number of primary segments that could be running on a host when mirror segments are activated due to a host or segment failure.

Resource queues and resource groups expose additional configuration parameters that enable you to further control and refine the amount of memory allocated for queries.

Example Memory Configuration Calculations

This section provides example memory calculations for resource queues and resource groups for a WarehousePG cluster with the following specifications:

- Total RAM = 256GB
- Swap = 64GB
- 8 primary segments and 8 mirror segments per host, in blocks of 4 hosts
- Maximum number of primaries per host during failure is 11

The `vm.overcommit_ratio` calculation for this example system follows:

```
gp_vmem = ((SWAP + RAM) – (7.5GB + 0.05 * RAM)) / 1.7
        = ((64 + 256) – (7.5 + 0.05 * 256)) / 1.7
        = 176

vm.overcommit_ratio = (RAM – (0.026 * gp_vmem)) / RAM
                    = (256 – (0.026 * 176)) / 256
                    = .982
```

You would set `vm.overcommit_ratio` of the example system to 98.

The `gp_vmem_protect_limit` calculation follows:

```
gp_vmem_protect_limit = gp_vmem / maximum_acting_primary_segments
                      = 176 / 11
                      = 16GB
                      = 16384MB
```

You would set the `gp_vmem_protect_limit` server configuration parameter on the example system to 16384.

Parent topic: Managing Performance

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4.10.5 WarehousePG memory calculator

This tool calculates recommended memory limits for WarehousePG environments. It is designed to maximize database memory utilization while maintaining a conservative buffer for Linux kernel operations, ensuring system stability even under high concurrency or heavy workloads.

Note: The content of this page is different to its equivalent in the open source repository https://github.com/warehouse-pg/whpg-docs #

import React, { useState } from 'react';

export function VmemCalculator() { const [systemMemory, setSystemMemory] = useState(64); const [swapMemory, setSwapMemory] = useState(32); const [otherMemory, setOtherMemory] = useState(0); const [segsPerNode, setSegsPerNode] = useState(8); const WHPGOtherMem = parseInt(otherMemory) || 0; const RAM = (parseInt(systemMemory) || 0) * 1024; const SWAP = (parseInt(swapMemory) || 0) * 1024; const NumOfSegs = (parseInt(segsPerNode) || 0); const USERMEM = (RAM + SWAP - ((7.5 * 1024) + (RAM * 0.05))); let MemSegPercent = .5882; if (RAM > 262144) { MemSegPercent = .85; } const KERNELMEM = (0.026 * (USERMEM / 1.7)); const OvercommitRatio = Math.floor((((RAM - KERNELMEM) / RAM) * 100) / 5) * 5; const SuggestedVmem = Math .round(Math.ceil(((((USERMEM - WHPGOtherMem) * MemSegPercent) / NumOfSegs)))); const InvalidParameters = WHPGOtherMem < 0 || RAM < 0 || SWAP < 0 || NumOfSegs < 0 || SuggestedVmem <=0 || OvercommitRatio <=0; return <>

{/* Line 1 */} System Memory (GB) <input className="form-control" name="SystemMemory" type="number" value={systemMemory} min="0" onChange={event => setSystemMemory(event.target.value)} />Swap Memory (GB) <input className="form-control" name="SwapMemory" type="number" value={swapMemory} min="0" onChange={event => setSwapMemory(event.target.value)} /> {/* Line 2 */} Other Memory (MB) <input className="form-control" name="OtherMemory" type="number" value={otherMemory} min="0" onChange={event => setOtherMemory(event.target.value)} /> Primary Segments <input className="form-control" name="SegsPerNode" type="number" value={segsPerNode} min="0" onChange={event => setSegsPerNode(event.target.value)} />
{InvalidParameters ?
Invalid Parameters
:
Recommended Max Settings

gp_vmem_protect_limit

Value in MB | configured in postgresql.conf, controlled by the gpconfig command
`gpconfig -c gp_vmem_protect_limit -v {SuggestedVmem}`

vm.overcommit_ratio

Percentage | configured in /etc/sysctl.conf
`vm.overcommit_ratio = {OvercommitRatio}`
} </>; }

export function AdvancedCalculator() { const [physicalMemory, setPhysicalMemory] = useState(512); const [swapSpace, setSwapSpace] = useState(32); const [segmentsPerHost, setSegmentsPerHost] = useState(10); const [concurrentQueries, setConcurrentQueries] = useState(50); const RAM = parseFloat(physicalMemory) || 0; const SWAP = parseFloat(swapSpace) || 0; const SEGS = parseFloat(segmentsPerHost) || 1; const QUERIES = parseFloat(concurrentQueries) || 1; let rq; if (RAM < 256) { rq = ((SWAP + RAM) - (7.5 + (0.05 * RAM))) / 1.7; } else { rq = ((SWAP + RAM) - (7.5 + (0.05 * RAM))) / 1.17; } const ratio = Math.floor(((RAM - (0.026 * rq)) / RAM) * 100); const protectLimit = Math.floor((rq * 1024) / SEGS); const stmtMem = Math.floor((protectLimit * 0.9) / QUERIES); const maxStmtMem = Math.floor((RAM * 1024) / QUERIES); const InvalidParameters = false; return <>

{/* Line 1 */} Segment Host Physical Memory (GB) <input className="form-control" name="adv_ram" type="number" value={physicalMemory} min="0" onChange={event => setPhysicalMemory(event.target.value)} />Segment Host Swap Space (GB) <input className="form-control" name="adv_swap" type="number" value={swapSpace} min="0" onChange={event => setSwapSpace(event.target.value)} /> {/* Line 2 */} Primary Segments per Host <input className="form-control" name="adv_segs" type="number" value={segmentsPerHost} min="1" onChange={event => setSegmentsPerHost(event.target.value)} /> Avg Concurrent Queries <input className="form-control" name="adv_queries" type="number" value={concurrentQueries} min="1" onChange={event => setConcurrentQueries(event.target.value)} />
{InvalidParameters ?
Invalid Parameters
:
Recommended Configuration

vm.overcommit_ratio

Kernel parameter sets % RAM used for app processes
`vm.overcommit_ratio = {ratio}`

gp_vmem_protect_limit

Memory limit (MB) for an active segment instance
`gpconfig -c gp_vmem_protect_limit -v {protectLimit}`

statement_mem

Standard query memory allocation
`statement_mem = {stmtMem}MB`

max_statement_mem

Maximum allowable query memory allocation
`max_statement_mem = {maxStmtMem}MB`

} </>; }

> **Notes**
>
> Choose the value for Primary Segments Per Node based on your mirroring strategy. See Overview of Segment Mirroring for more information on group and spread mirroring strategies.
>
> - Given a configuration of 6 primaries and 6 mirrors, we should set Primary Segments Per Node to 6+6=12 when using group mirroring.
> - Using the same configuration example for spread mirroring, the value would be 6+2=8.
>
> For more information on memory, please refer to theWarehousePG Memory Overview.

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4.10.6 Managing Resources

WarehousePG provides features to help you prioritize and allocate resources to queries according to business requirements and to prevent queries from starting when resources are unavailable.

You can use resource management features to limit the number of concurrent queries, the amount of memory used to run a query, and the relative amount of CPU devoted to processing a query. WarehousePG provides two schemes to manage resources: Resource Queues and Resource Groups.

Either the resource queue or the resource group management scheme can be active in WarehousePG; both schemes cannot be active at the same time. Set the server configuration parameter gp_resource_manager to enable the preferred scheme in the WarehousePG cluster.

The following table summarizes some of the differences between resource queues and resource groups.

Metric	Resource Queues	Resource Groups
Concurrency	Defines the number of query slots available at a time	Defines the number of transaction slots available at a time
CPU	Specify query priority	Specify percentage of CPU resources or the specific number of CPU cores; uses Linux Control Groups
Memory	Managed at the queue and operator level; users can over-subscribe	Managed at the transaction level, with enhanced allocation and tracking; users can over-subscribe
Users	Limits are applied only to non-admin users	Limits are applied to `SUPERUSER`, non-admin users, and system processes of non-user classes
Disk I/O	None	Limit the maximum read/write disk I/O throughput, and maximum read/write I/O operations per second
Queueing	Queue when no slot available or not enough available memory	Queue only when no slot is available
Query Failure	Query may fail immediately if the allocated memory for the query surpasses the available system memory and spill limits	Query may fail if the allocated memory for the query surpasses the available system memory and spill limits
Limit Bypass	Limits are not enforced for `SUPERUSER` roles and certain operators and functions	Limits are not enforced on `SET`, `RESET`, and `SHOW` commands. Additionally, certain queries may be configured to bypass the concurrency limit
External Components	None	Manage PL/Container CPU resources

Parent topic: Managing Performance

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4.10.6.1 About Changes to Resource Groups in WarehousePG 7

WarehousePG 7 introduces substantial changes to resource group-based resource management. This topic compares the differences between resource groups with WarehousePG 6 and WarehousePG 7. Visit Using Resource Groups for more information about how resource groups work in WarehousePG 7.

The following table compares the main concepts of resource management and how each version of WarehousePG implements them:

Metric	Resource Groups in WarehousePG 6	Resource Groups in WarehousePG 7
Concurrency	Managed at the transaction level	Managed at the transaction level
CPU	Specify percentage of CPU resources or the number of CPU cores; uses Linux Control Groups	Specify percentage of CPU resources or the number of CPU cores, as well as set upper limits per resource group; uses Linux Control Groups
Memory	Managed at the transaction level, with enhanced allocation and tracking; users cannot over-subscribe	Managed at the transaction level, with enhanced allocation and tracking; users can over-subscribe; simpler and more convenient configuration
Disk I/O	None	Limit the maximum read/write disk I/O throughput, and maximum read/write I/O operations per second
Users	Limits are applied to `SUPERUSER` and non-admin users alike There are two default resource groups: `admin_group` and `default_group`	Limits are applied to `SUPERUSER`, non-admin users, and system processes of non-user classes There are three default resource groups: `admin_group`, `default_group`, and `system_group`
Queueing	Queue when no slot is available or not enough available memory	Queue when no slot is available
Query Failure	Query may fail after reaching transaction fixed memory limit when no shared resource group memory exists and the transaction requests more memory	Query may fail if the allocated memory for the query surpasses the available system memory and spill limits
Limit Bypass	Limits are not enforced on `SET`, `RESET`, and `SHOW` commands	Limits are not enforced on `SET`, `RESET`, and `SHOW` commands. Additionally, certain queries may be configured to bypass the concurrency limit
External Components	Manage PL/Container CPU and memory resources	Manage PL/Container CPU resources

> **Note** Disk I/O limits are only available when you use Linux Control Groups v2. See Configuring and Using Resource Groups for more information.

Changes to Resource Groups Attributes

You may configure four new resource group attributes using the `CREATE RESOURCE GROUP` and `ALTER RESOURCE GROUP` SQL commands:

- `CPU_MAX_PERCENT`, which configures the maximum amount of CPU resources the resource group can use.
- `CPU_WEIGHT`, which configures the scheduling priority of the resource group.
- `MIN_COST`, which configures the minimum amount a query's query plan cost for the query to remain in the resource group.
- `IO_LIMIT`, which configures device I/O usage at the resource group level to manage the maximum throughput of read/write operations, and the maximum read/write operations per second.

The following resource group attributes have been removed:

- `CPU_RATE_LIMIT`
- `MEMORY_AUDITOR`
- `MEMORY_SPILL_RATIO`
- `MEMORY_SHARED_QUOTA`

Changes to Server Configuration Parameters

WarehousePG 7 resource group management introduces the following changes to server configuration parameters:

- The possible settings for the gp_resource_manager server configuration parameter have changed. They now include the following:
  - `none` - Configures WarehousePG to not use any resource manager. This is the default.
  - `group` - Configures WarehousePG to use resource groups and base resource group behavior on the cgroup v1 version of Linux cgroup functionality.
  - `group-v2` - Configures WarehousePG to use resource groups and base resource group behavior on the cgroup v2 version of Linux cgroup functionality.
  - `queue` - Configures WarehousePG to use resource queues.
- The new server configuration parameter gp_resgroup_memory_query_fixed_mem allows you to override at a session level the fixed amount of memory reserved for all queries in a resource group.
- The new server configuration parameter gp_resource_group_move_timeout cancels the `pg_resgroup_move_query()` function, which moves a running query from one resouce group to another, if it waits longer than the specified number of miliseconds.
- The new server configuration parameter gp_resource_group_bypass_direct_dispatch bypasses the resource group's limits for a direct dispatch query so it can run immediately. A direct dispatch query is a special type of query that only requires a single segment to participate in the execution.
- The server configuration parameter `gp_resource_group_cpu_ceiling_enforcement` has been removed.
- The server configuration parameter `gp_resource_group_enable_recalculate_query_mem` has been removed.
- The server configuration parameter `gp_resource_group_memory_limit` has been removed.

Changes to System Views

The following system views have changes:

- The fields `cpu_rate_limit`, `memory_shared_quota`, `memory_spill_ratio`, and `memory_auditor` have been replaced by `cpu_max_percent`, `cpu_weight`, `cpuset`, `min_cost`, and `io_limit` in the `gp_resgroups_config` system view.
- The field `rsgname` has been renamed to `groupname` in the `gp_resgroup_status` system view.
- The fields `cpu_usage` and `memory_usage` have been removed from the `gp_resgroup_status` system view to the `gp_resgroup_status_per_host` system view.
- The fields `hostname`, `cpu`, `memory_used`, `memory_available`, `memory_quota_used`, `memory_quota_available`, `memory_shared_used`, and `memory_shared_available` have been removed from the system view `gp_resgroup_status_per_host`. The fields `segment_id`, `cpu_usage` and `memory_usage` have been added to the view.

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- The fields `rsgname`, `hostname`, `cpu`, `memory_used`, `memory_available`, `memory_quota_used`, `memory_quota_available`, `memory_shared_used`, and `memory_shared_available` have been removed from the system view `gp_resgroup_status_per_segment`. The fields `groupname`, and `vmem_usage` have been added to the view.
- The `gp_resgroup_iostats_per_host` system view has been added.

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4.10.6.2 Using Resource Groups

You use resource groups to manage and protect the resource allocation of CPU, memory, concurrent transaction limits, and disk I/O in WarehousePG. Once you define a resource group, you assign the group to one or more WarehousePG roles, or to an external component such as PL/Container, in order to control the resources used by them.

When you assign a resource group to a role, the resource limits that you define for the group apply to all of the roles to which you assign the group. For example, the memory limit for a resource group identifies the maximum memory usage for all running transactions submitted by WarehousePG users in all roles to which you assign the group.

WarehousePG uses Linux-based control groups for CPU resource management, and Runaway Detector for statistics, tracking and management of memory.

When using resource groups to control resources like CPU cores, review the Hyperthreading note in Hardware and Network.

Parent topic: Managing Resources

Understanding Role and Component Resource Groups

WarehousePG supports two types of resource groups: groups that manage resources for roles, and groups that manage resources for external components such as PL/Container.

The most common application for resource groups is to manage the number of active queries that different roles may run concurrently in your WarehousePG cluster. You can also manage the amount of CPU, memory resources, and disk I/O that WarehousePG allocates to each query.

When a user runs a query, WarehousePG evaluates the query against a set of limits defined for the resource group. WarehousePG runs the query immediately if the group's resource limits have not yet been reached and the query does not cause the group to exceed the concurrent transaction limit. If these conditions are not met, WarehousePG queues the query. For example, if the maximum number of concurrent transactions for the resource group has already been reached, a subsequent query is queued and must wait until other queries complete before it runs. WarehousePG may also run a pending query when the resource group's concurrency and memory limits are altered to large enough values.

Within a resource group for roles, transactions are evaluated on a first in, first out basis. WarehousePG periodically assesses the active workload of the system, reallocating resources and starting/queuing jobs as necessary.

You can also use resource groups to manage the CPU and memory resources of external components such as PL/Container. Resource groups for external components use Linux cgroups to manage the total CPU resources for the component.

Resource Group Attributes and Limits

When you create a resource group, you provide a set of limits that determine the amount of CPU and memory resources available to the group. The following table lists the available limits for resource groups:

Limit Type	Description	Value Range	Default
CONCURRENCY	The maximum number of concurrent transactions, including active and idle transactions, that are permitted in the resource group.	[0 - max_connections]	20
CPU_MAX_PERCENT	The maximum percentage of CPU resources the group can use.	[1 - 100]	-1 (not set)
CPU_WEIGHT	The scheduling priority of the resource group.	[1 - 500]	100
CPUSET	The specific CPU logical core (or logical thread in hyperthreading) reserved for this resource group.	It depends on system core configuration	-1
IO_LIMIT	The limit for the maximum read/write disk I/O throughput, and maximum read/write I/O operations per second. Set the value on a per-tablespace basis.	[2 - 4294967295 or `max`]	-1
MEMORY_QUOTA	The memory limit value specified for the resource group.	Integer (MB)	-1 (not set, use `statement_mem` as the memory limit for a single query)
MIN_COST	The minimum cost of a query plan to be included in the resource group.	Integer	0

> **Note** Resource limits are not enforced on `SET`, `RESET`, and `SHOW` commands.

Transaction Concurrency Limit

The `CONCURRENCY` limit controls the maximum number of concurrent transactions permitted for a resource group.

Each resource group is logically divided into a fixed number of slots equal to the `CONCURRENCY` limit. WarehousePG allocates these slots an equal, fixed percentage of memory resources.

The default `CONCURRENCY` limit value for a resource group for roles is 20. A value of 0 means that no query is allowed to run for this resource group.

WarehousePG queues any transactions submitted after the resource group reaches its `CONCURRENCY` limit. When a running transaction completes, WarehousePG un-queues and runs the earliest queued transaction if sufficient memory resources exist. Note that if a transaction is in `idle in transaction` state, even if no statement is running, the concurrency slot is still in use.

You can set the server configuration parameter gp_resource_group_queuing_timeout to specify the amount of time a transaction remains in the queue before WarehousePG cancels the transaction. The default timeout is zero, WarehousePG queues transactions indefinitely.

Bypass and Unassign from Resource Groups

A query bypasses the resource group concurrency limit if you set the server configuration parameter gp_resource_group_bypass. This parameter enables or disables the concurrent transaction limit for the resource group so a query can run immediately. The default value is false, which enforces the limit of the `CONCURRENCY` limit. You may only set this parameter for a single session, not within a transaction or a function. If you set `gp_resource_group_bypass` to true, the query no longer enforces the CPU or memory limits assigned to its resource group. Instead, the memory quota assigned to this query is `statement_mem` per query. If there is not enough memory to satisfy the memory allocation request, the query will fail.

You may bypass queries that only use catalog tables, such as the database Graphical User Interface (GUI) client, which runs catalog queries to obtain metadata. If the server configuration parameter gp_resource_group_bypass_catalog_query is set to true (the default), WarehousePG's resource group scheduler bypasses all queries that read exclusively from system catalogs, or queries that contain in their query text `pg_catalog` schema tables only. These queries are automatically unassigned from its current resource group; they do not enforce the limits of the resource group and do not account for resource usage. The query resources are assigned out of the resource groups and run immediately. The memory quota is `statement_mem` per the query.

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You may bypass direct dispatch queries with the server configuration parameter gp_resource_group_bypass_direct_dispatch. A direct dispatch query is a special type of query that only requires a single segment to participate in the execution. In order to improve efficiency, WarehousePG optimizes this type of query, using direct dispatch optimization. The system sends the query plan to the execution of a single segment that needs to execute the plan, instead of sending it to all segments for execution. If you set `gp_resource_group_bypass_direct_dispatch` to true, the query no longer enforces the CPU or memory limits assigned to its resource group, so it runs immediately. Instead, the memory quota assigned to this query is `statement_mem` per query. If there is not enough memory to satisfy the memory allocation request, the query will fail. You may only set this parameter for a single session, not within a transaction or a function.

Queries whose plan cost is less than the limit `MIN_COST` are automatically unassigned from their resource group and do not enforce any of its limits. The resources used by the query do not account for the resources of the resource group. The query has a memory quota of `statement_mem`. The default value of `MIN_COST` is 0.

CPU Limits

WarehousePG leverages Linux control groups to implement CPU resource management. WarehousePG allocates CPU resources in two ways:

- By assigning a percentage of CPU resources to resource groups.
- By assigning specific CPU cores to resource groups

When you set one of the allocation modes for a resource group, WarehousePG deactivates the other allocation mode. You may employ both modes of CPU resource allocation simultaneously for different resource groups on the same WarehousePG cluster. You may also change the CPU resource allocation mode for a resource group at runtime.

WarehousePG uses the server configuration parameter gp_resource_group_cpu_limit to identify the maximum percentage of system CPU resources to allocate to resource groups on each WarehousePG segment node. The remaining unreserved CPU resources are used for the operating system kernel and WarehousePG daemons. The amount of CPU available to WarehousePG queries per host is then divided equally among each segment on the WarehousePG node.

> **Note** The default `gp_resource_group_cpu_limit` value may not leave sufficient CPU resources if you are running other workloads on your WarehousePG cluster nodes, so be sure to adjust this server configuration parameter accordingly.

> **Caution** Avoid setting `gp_resource_group_cpu_limit` to a value higher than .9. Doing so may result in high workload queries taking near all CPU resources, potentially starving WarehousePG auxiliary processes.

Assigning CPU Resources by Core

You identify the CPU cores that you want to reserve for a resource group with the `CPUSET` property. The CPU cores that you specify must be available in the system and cannot overlap with any CPU cores that you reserved for other resource groups. Although WarehousePG uses the cores that you assign to a resource group exclusively for that group, note that those CPU cores may also be used by non-WarehousePG processes in the system. When you configure `CPUSET` for a resource group, WarehousePG deactivates `CPU_MAX_PERCENT` and `CPU_WEIGHT` for the group and sets their value to -1.

Specify CPU cores separately for the coordinator host and segment hosts, separated by a semicolon. Use a comma-separated list of single core numbers or number intervals when you configure cores for `CPUSET`. You must enclose the core numbers/intervals in single quotes, for example, '1;1,3-4' uses core 1 on the coordinator host, and cores 1, 3, and 4 on segment hosts.

When you assign CPU cores to `CPUSET` groups, consider the following:

- A resource group that you create with `CPUSET` uses the specified cores exclusively. If there are no running queries in the group, the reserved cores are idle and cannot be used by queries in other resource groups. Consider minimizing the number of `CPUSET` groups to avoid wasting system CPU resources.
- Consider keeping CPU core 0 unassigned. CPU core 0 is used as a fallback mechanism in the following cases:
  - `admin_group` and `default_group` require at least one CPU core. When all CPU cores are reserved, WarehousePG assigns CPU core 0 to these default groups. In this situation, the resource group to which you assigned CPU core 0 shares the core with `admin_group` and `default_group`.
  - If you restart your WarehousePG cluster with one node replacement and the node does not have enough cores to service all `CPUSET` resource groups, the groups are automatically assigned CPU core 0 to avoid system start failure.

- Use the lowest possible core numbers when you assign cores to resource groups. If you replace a WarehousePG node and the new node has fewer CPU cores than the original, or if you back up the database and want to restore it on a cluster with nodes with fewer CPU cores, the operation may fail. For example, if your WarehousePG cluster has 16 cores, assigning cores 1-7 is optimal. If you create a resource group and assign CPU core 9 to this group, database restore to an 8 core node will fail.

Resource groups that you configure with `CPUSET` have a higher priority on CPU resources. The maximum CPU resource usage percentage for all resource groups configured with `CPUSET` on a segment host is the number of CPU cores reserved divided by the number of all CPU cores, multiplied by 100.

> **Note** You must configure `CPUSET` for a resource group *after* you have enabled resource group-based resource management for your WarehousePG cluster with the gp_resource_manager server configuration parameter.

Assigning CPU Resources by Percentage

You configure a resource group with `CPU_MAX_PERCENT` in order to assign CPU resources by percentage. When you configure `CPU_MAX_PERCENT` for a resource group, WarehousePG deactivates `CPUSET` for the group.

The parameter `CPU_MAX_PERCENT` sets a hard upper limit for the percentage of the segment CPU for resource management. The minimum `CPU_MAX_PERCENT` percentage you can specify for a resource group is 1, the maximum is 100. The sum of `CPU_MAX_PERCENT` s specified for all resource groups that you define in your WarehousePG cluster can exceed 100. It specifies the total time ratio that all tasks in a resource group can run in a given CPU time period. Once the tasks in the resource group have used up all the time specified by the quota, they are throttled for the remainder of the time specified in that time period, and are not allowed to run until the next time period.

When tasks in a resource group are idle and not using any CPU time, the leftover time is collected in a global pool of unused CPU cycles. Other resource groups can borrow CPU cycles from this pool. The actual amount of CPU time available to a resource group may vary, depending on the number of resource groups present on the system.

The parameter `CPU_MAX_PERCENT` enforces a hard upper limit of CPU usage. For example, if it is set to 40%, it indicates that although the resource group can temporarily use some idle CPU resources from other groups, the maximum it can use is 40% of the CPU resources available to WarehousePG.

You set the parameter `CPU_WEIGHT` to assign the scheduling priority of the current group. The default value is 100, and the range of values is 1 to 500. The value specifies the relative share of CPU time available to tasks in the resource group. For example, if one resource group has a relative share of 100 and another two groups have a relative share of 50, when processes in all the resource groups try to use 100% of the CPU (that means, the value of `CPU_MAX_PERCENT` for all groups is set to 100), the first resource group gets 50% of all CPU time, and the other two get 25% each. However, if you add another group with a relative share of 100, the first group is only allowed to use 33% of the CPU, and the remaining groups get 16.5%, 16.5%, and 33% respectively.

For example, consider the following groups:

Group Name	CONCURRENCY	CPU_MAX_PERCENT	CPU_WEIGHT
default_group	20	50	10
admin_group	10	70	30
system_group	10	30	10
test	10	10	10

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Roles in `default_group` have an available CPU ratio (determined by `CPU_WEIGHT`) of 10/(10+30+10+10)=16%. This means that they can use at least 16% of the CPU when the system workload is high. When the system has idle CPU resources, they can use more resources, as the hard limit (set by `CPU_MAX_PERCENT`) is 50%.

Roles in `admin_group` have an available CPU ratio of 30/(10+30+10+10)=50% when the system workload is high. When the system has idle CPU resources, they can use resources up to the hard limit of 70%.

Roles in `test` have a CPU ratio of 10/(10+30+10+10)=16%. However, as the hard limit determined by `CPU_MAX_PERCENT` is 10%, they can only use up to 10% of the resources even when the system is idle.

Memory Limits

When you enable resource groups, memory usage is managed at the WarehousePG segment and resource group levels. You can also manage memory at the transaction level. See WarehousePG Memory Overview to estimate how much memory each WarehousePG segment has available to use. This will help you estimate how much memory to assign to the resource groups.

The amount of memory allocated to a query is determined by the following parameters:

The parameter `MEMORY_QUOTA` of a resource group sets the maximum amount of memory reserved for this resource group on a segment. This determines the total amount of memory that all worker processes for a query can consume on the segment host during query execution. The amount of memory allotted to a query is the group memory limit divided by the group concurrency limit: `MEMORY_QUOTA` / `CONCURRENCY`.

If a query requires a large amount of memory, you may use the server configuration parameter gp_resgroup_memory_query_fixed_mem to set a fixed memory amount for the query at the session level. This parameter overrides and can surpass the allocated memory of the resource group.

WarehousePG allocates memory for an incoming query using the `gp_resgroup_memory_query_fixed_mem` value, if set, to bypass the resource group settings. Otherwise, it uses `MEMORY_QUOTA` / `CONCURRENCY` as the memory allocated for the query. If `MEMORY_QUOTA` is not set, the value for the query memory allocation defaults to statement_mem.

For all queries, if there is not enough memory in the system, they spill to disk. When the limit gp_workfile_limit_files_per_query is reached, WarehousePG generates an out of memory (OOM) error.

For example, consider a resource group named `adhoc` with `MEMORY_QUOTA` set to 1.5 GB and `CONCURRENCY` set to 3. By default, each statement submitted to the group is allocated 500 MB of memory. Now consider the following series of events:

1. User `ADHOC_1` submits query `Q1`, overriding `gp_resgroup_memory_query_fixed_mem` to 800MB. The `Q1` statement is admitted into the system.
2. User `ADHOC_2` submits query `Q2`, using the default 500MB.
3. With `Q1` and `Q2` still running, user `ADHOC3` submits query `Q3`, using the default 500MB.

   Queries `Q1` and `Q2` have used 1300MB of the group's 1500MB. However, if there is enough system memory available for query `Q3` in the segment at that time, it can run normally.
4. User `ADHOC4` submits query `Q4`, using `gp_resgroup_memory_query_fixed_mem` set to 700 MB.

   Query `Q4` runs immediately as it bypasses the resource group limits.

There are some special usage considerations regarding memory limits:

- If you set the configuration parameters `gp_resource_group_bypass` or `gp_resource_group_bypass_catalog_query` to bypass the resource group limits, the memory limit for the query takes the value of `statement_mem`.
- When (`MEMORY_QUOTA` / `CONCURRENCY`) < `statement_mem`, WarehousePG uses `statement_mem` as the fixed amount of memory allocated by query.
- The maximum value of `statement_mem` is capped at max_statement_mem.
- Queries whose plan cost is less than the limit `MIN_COST` use a memory quota of `statement_mem`.

Disk I/O Limits

WarehousePG leverages Linux control groups to implement disk I/O limits. The parameter `IO_LIMIT` limits the maximum read/write disk I/O throughput, and the maximum read/write I/O operations per second for the queries assigned to a specific resource group. It allocates bandwidth, ensures the use of high-priority resource groups, and avoids excessive use of disk bandwidth. The value of the parameter is set on a per-tablespace basis.

> **Note** Disk I/O limits are only available when you use Linux Control Groups v2. See Configuring and Using Resource Groups for more information.

When you limit disk I/O you specify:

- The tablespace name or the tablespace object ID (OID) you set the limits for. Use `*` to set limits for all tablespaces.
- The values for `rbps` and `wbps` to limit the maximum read and write disk I/O throughput in the resource group, in MB/sec. The default value is `max`, which means there is no limit.
- The values for `riops` and `wiops` to limit the maximum read and write I/O operations per second in the resource group. The default value is `max`, which means there is no limit.

If the parameter `IO_LIMIT` is not set, the default value for `rbps`, `wpbs`, `riops`, and `wiops` s is set to `max`, which means that there are no disk I/O limits. In this scenario, the `gp_toolkit.gp_resgroup_config` system view displays its value as `-1`. If only some of the values of `IO_LIMIT` are set (for example. `rbps`), the parameters that are not set default to `max` (in this example, `wbps`, `riops`, wiops`).

Configuring and Using Resource Groups

Prerequisites

WarehousePG resource groups use Linux Control Groups (cgroups) to manage CPU resources and disk I/O. There are two versions of cgroups: cgroup v1 and cgroup v2. WarehousePG 7 supports both versions, but it only supports the parameter `IO_LIMIT` for cgroup v2. The version of Linux Control Groups shipped by default with your Linux distribution depends on the operating system version. For Enterprise Linux 8 and older, the default version is v1. For Enterprise Linux 9 and later, the default version is v2. For detailed information about cgroups, refer to the Control Groups documentation for your Linux distribution.

Verify what version of cgroup is configured in your environment by checking what filesystem is mounted by default during system boot:

```
stat -fc %T /sys/fs/cgroup/
```

For cgroup v1, the output is `tmpfs`. For cgroup v2, output is `cgroup2fs`.

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You do not need to change your version of cgroup, you can simply skip to Configuring cgroup v1 or Configuring cgroup v2 in order to complete the configuration prerequisites. However, if you prefer to switch from cgroup v1 to v2, run the following commands as root:

- Red Hat 8/Rocky 8/Oracle 8 systems:

```
grubby --update-kernel=/boot/vmlinuz-$(uname -r) --args="systemd.unified_cgroup_hierarchy=1"
```

- Ubuntu systems:

```
vim /etc/default/grub
# add or modify: GRUB_CMDLINE_LINUX="systemd.unified_cgroup_hierarchy=1"
update-grub
```

If you want to switch from cgroup v2 to v1, run the following commands as root:

- Red Hat 8/Rocky 8/Oracle 8 systems:

```
grubby --update-kernel=/boot/vmlinuz-$(uname -r) --args="systemd.unified_cgroup_hierarchy=0 systemd.legacy_systemd_cgroup_controller"
```

- Ubuntu systems:

```
vim /etc/default/grub
# add or modify: GRUB_CMDLINE_LINUX="systemd.unified_cgroup_hierarchy=0"
update-grub
```

After that, reboot your host in order for the changes to take effect.

Configuring cgroup v1

Complete the following tasks on each node in your WarehousePG cluster to set up cgroups v1 for use with resource groups:

1. Locate the cgroups configuration file `/etc/cgconfig.conf`. You must be the superuser or have `sudo` access to edit this file:

   ```
   vi /etc/cgconfig.conf
   ```

2. Add the following configuration information to the file:

   ```
   group gpdb {
        perm {
            task {
                uid = gpadmin;
                gid = gpadmin;
            }
            admin {
                uid = gpadmin;
                gid = gpadmin;
            }
        }
        cpu {
        }
        cpuacct {
        }
        cpuset {
        }
        memory {
        }
   }
   ```

   This content configures CPU, CPU accounting, CPU core set, and memory control groups managed by the `gpadmin` user. WarehousePG uses the memory control group only for monitoring the memory usage.

3. Start the cgroups service on each WarehousePG node. For Redhat/Oracle/Rocky 8.x and older, run the following as root:

   ```
   cgconfigparser -l /etc/cgconfig.conf
   ```

4. To automatically recreate WarehousePG required cgroup hierarchies and parameters when your system is restarted, configure your system to enable the Linux cgroup service daemon `cgconfig.service` at node start-up. To ensure the configuration is persisten after reboot, run the following commands as user root. For Redhat/Oracle/Rocky 8.x and older:

   ```
   systemctl enable cgconfig.service
   ```

   To start the service immediately (without having to reboot) enter:

   ```
   systemctl start cgconfig.service
   ```

5. Identify the `cgroup` directory mount point for the node. For Redhat/Oracle/Rocky 8.x and older, run the following as root:

   ```
   grep cgroup /proc/mounts
   ```

   The first line of output identifies the `cgroup` mount point.

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6. Verify that you set up the WarehousePG cgroups configuration correctly by running the following commands. Replace \<cgroup_mount_point> with the mount point that you identified in the previous step:

```
ls -l <cgroup_mount_point>/cpu/gpdb
ls -l <cgroup_mount_point>/cpuset/gpdb
ls -l <cgroup_mount_point>/memory/gpdb
```

   If these directories exist and are owned by `gpadmin:gpadmin`, you have successfully configured cgroups for WarehousePG resource management.

Configuring cgroup v2

1. Configure the system to mount `cgroups-v2` by default during system boot by the `systemd` system and service manager as user root.

```
grubby --update-kernel=ALL --args="systemd.unified_cgroup_hierarchy=1"
```

2. Reboot the system for the changes to take effect.

```
reboot now
```

3. Create the directory `/sys/fs/cgroup/gpdb`, add all the necessary controllers, and ensure `gpadmin` user has read and write permission on it.

```
mkdir -p /sys/fs/cgroup/gpdb
echo "+cpuset +io +cpu +memory" | tee -a /sys/fs/cgroup/cgroup.subtree_control
chown -R gpadmin:gpadmin /sys/fs/cgroup/gpdb
```

You may encounter the error `Invalid argument` after running the above commands. This is because cgroups v2 do not support control of real-time processes, and the `cpu` controller can only be enabled when all the real-time processes are in the root cgroup. In this situation, find all real-time processes and move them to the root cgroup before you re-enable the controllers.

1. Ensure that `gpadmin` has write permission on `/sys/fs/cgroup/cgroup.procs`. This is required to move the WarehousePG processes from the user slices to `/sys/fs/cgroup/gpdb/` after the cluster is started in order to manage the postmaster services and all its auxiliary processes.

```
```
chmod a+w /sys/fs/cgroup/cgroup.procs
```
```

   Since resource groups manually manage cgroup files, the above settings will become ineffective after a system reboot. Add the following bash script for systemd so it runs automatically during system startup. Perform the following steps as user root:

2. Create `gpdb.service`.

```
vim /etc/systemd/system/gpdb.service
```

3. Write the following content into `gpdb.service`, if the user is not `gpadmin`, replace it with the appropriate user.

```
[Unit]
Description=WarehousePG Cgroup v2 Configuration Service
[Service]
Type=simple
WorkingDirectory=/sys/fs/cgroup/gpdb.service
Delegate=yes
Slice=-.slice

# set hierarchies only if cgroup v2 mounted
ExecCondition=bash -c '[ xcgroup2fs = x$(stat -fc "%%T" /sys/fs/cgroup) ] || exit 1'
ExecStartPre=bash -ec " \
chown -R gpadmin:gpadmin .; \
chmod a+w ../cgroup.procs; \
mkdir -p helper.scope"
ExecStart=sleep infinity
ExecStartPost=bash -ec "echo $MAINPID > ./helper.scope/cgroup.procs;"
[Install]
WantedBy=basic.target
```

4. Reload systemd daemon and enable the service:

```
systemctl daemon-reload
systemctl enable gpdb.service
```

Enabling Resource Groups

When you install WarehousePG, no resource management policy is enabled by default. To use resource groups, set the gp_resource_manager server configuration parameter.

1. Set the `gp_resource_manager` server configuration parameter to the value `"group"` or `"group-v2"`, depending on the version of cgroup configured on your Linux distribution. For example:

```
gpconfig -c gp_resource_manager -v "group"
gpconfig -c gp_resource_manager -v "group-v2"
```

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2. Restart WarehousePG:

```
gpstop
gpstart
```

Once enabled, any transaction submitted by a role is directed to the resource group assigned to the role, and is governed by that resource group's concurrency, memory, CPU, and disk I/O limits.

WarehousePG creates three default resource groups for roles named `admin_group`, `default_group`, and `system_group`. When you enable resources groups, any role that was not explicitly assigned a resource group is assigned the default group for the role's capability. `SUPERUSER` roles are assigned the `admin_group`, non-admin roles are assigned the group named `default_group`. The resources of the WarehousePG cluster processes are assigned to the `system_group`. You cannot manually assign any roles to the `system_group`.

The default resource groups `admin_group`, `default_group`, and `system_group` are created with the following resource limits:

Limit Type	admin_group	default_group	system_group
CONCURRENCY	10	5	0
CPU_MAX_PERCENT	10	20	10
CPU_WEIGHT	100	100	100
CPUSET	-1	-1	-1
IO_LIMIT	-1	-1	-1
MEMORY_LIMIT	-1	-1	-1
MIN_COST	0	0	0

Creating Resource Groups

When you create a resource group for a role, you provide a name and a CPU resource allocation mode (core or percentage). You can optionally provide a concurrent transaction limit, a memory limit, a CPU soft priority, disk I/O limits, and a minimum cost. Use the CREATE RESOURCE GROUP command to create a new resource group.

When you create a resource group for a role, you must provide a `CPU_MAX_PERCENT` or `CPUSET` limit value. These limits identify the percentage of WarehousePG CPU resources to allocate to this resource group. You may specify a `MEMORY_QUOTA` to reserve a fixed amount of memory for the resource group.

For example, to create a resource group named *rgroup1* with a CPU limit of 20, a memory limit of 25, a CPU soft priority of 500, a minimum cost of 50, and disk I/O limits for the `pg_default` tablespace:

```
CREATE RESOURCE GROUP rgroup1 WITH (CONCURRENCY=20, CPU_MAX_PERCENT=20, MEMORY_QUOTA=250, CPU_WEIGHT=500, MIN_COST=50,
  IO_LIMIT='pg_default: wbps=1000, rbps=1000, wiops=100, riops=100');
```

The CPU limit of 20 is shared by every role to which `rgroup1` is assigned. Similarly, the memory limit of 25 is shared by every role to which `rgroup1` is assigned. `rgroup1` utilizes the default `CONCURRENCY` setting of 20.

The ALTER RESOURCE GROUP command updates the limits of a resource group. To change the limits of a resource group, specify the new values that you want for the group. For example:

```
ALTER RESOURCE GROUP rg_role_light SET CONCURRENCY 7;
ALTER RESOURCE GROUP exec SET MEMORY_QUOTA 30;
ALTER RESOURCE GROUP rgroup1 SET CPUSET '1;2,4';
ALTER RESOURCE GROUP sales SET IO_LIMIT 'tablespace1:wbps=2000,wiops=2000;tablespace2:rbps=2024,riops=2024';
```

> **Note** You cannot set or alter the `CONCURRENCY` value for the `admin_group` to zero (0).

The DROP RESOURCE GROUP command drops a resource group. To drop a resource group for a role, the group cannot be assigned to any role, nor can there be any transactions active or waiting in the resource group.

To drop a resource group:

```
DROP RESOURCE GROUP exec;
```

Configuring Automatic Query Termination Based on Memory Usage

WarehousePG supports the Runaway detector, which automatically terminates queries based on the amount of memory used by the query. For resource group-managed queries, WarehousePG terminates a running query based on the amount of memory used by the query. The relevant configuration parameters are:

- gp_vmem_protect_limit sets the amount of memory that all `postgres` processes of the active segment instance can consume. If a query causes this limit to be exceeded, no memory will be allocated and the query will fail.
- runaway_detector_activation_percent. When resource groups are enabled, if the used memory exceeds the specified value `gp_vmem_protect_limit` * `runaway_detector_activation_percent`, WarehousePG terminates queries based on memory usage, selecting queries from the queries managed by user resource groups (excluding those in the `system_group` resource group). WarehousePG starts with the query that consumes the largest amount of memory. The query will terminate until the percentage of memory used falls below the specified percentage.

Assigning a Resource Group to a Role

You assign a resource group to a database role using the `RESOURCE GROUP` clause of the CREATE ROLE or ALTER ROLE commands. If you do not specify a resource group for a role, the role is assigned the default group for the role's capability. `SUPERUSER` roles are assigned the `admin_group`, non-admin roles are assigned the group named `default_group`.

Use the `ALTER ROLE` or `CREATE ROLE` commands to assign a resource group to a role. For example:

```
ALTER ROLE bill RESOURCE GROUP rg_light;
CREATE ROLE mary RESOURCE GROUP exec;
```

You can assign a resource group to one or more roles. If you have defined a role hierarchy, assigning a resource group to a parent role does not propagate down to the members of that role group.

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If you wish to remove a resource group assignment from a role and assign the role the default group, change the role's group name assignment to `NONE`. For example:

```
ALTER ROLE mary RESOURCE GROUP NONE;
```

Monitoring Resource Group Status

Monitoring the status of your resource groups and queries may involve the following tasks.

Viewing Resource Group Limits

The gp_resgroup_config `gp_toolkit` system view displays the current limits for a resource group. To view the limits of all resource groups:

```
SELECT * FROM gp_toolkit.gp_resgroup_config;
```

Viewing Resource Group Query Status

The gp_resgroup_status `gp_toolkit` system view enables you to view the status and activity of a resource group. The view displays the number of running and queued transactions. To view this information:

```
SELECT * FROM gp_toolkit.gp_resgroup_status;
```

Viewing Resource Group Memory Usage Per Host

The gp_resgroup_status_per_host `gp_toolkit` system view enables you to view the real-time memory usage of a resource group on a per-host basis. To view this information:

```
SELECT * FROM gp_toolkit.gp_resgroup_status_per_host;
```

Viewing the Resource Group Assigned to a Role

To view the resource group-to-role assignments, perform the following query on the pg_roles and pg_resgroup system catalog tables:

```
SELECT rolname, rsgname FROM pg_roles, pg_resgroup
WHERE pg_roles.rolresgroup=pg_resgroup.oid;
```

Viewing Resource Group Disk I/O Usage Per Host

The gp_resgroup_iostats_per_host `gp_toolkit` system view enables you to view the real-time disk I/O usage of a resource group on a per-host basis. To view this information:

```
SELECT * FROM gp_toolkit.gp_resgroup_iostats_per_host;
```

Viewing a Resource Group's Running and Pending Queries

To view a resource group's running queries, pending queries, and how long the pending queries have been queued, examine the pg_stat_activity system catalog table:

```
SELECT query, rsgname,wait_event_type, wait_event
FROM pg_stat_activity;
```

`pg_stat_activity` displays information about the user/role that initiated a query. A query that uses an external component such as PL/Container is composed of two parts: the query operator that runs in WarehousePG and the UDF that runs in a PL/Container instance. WarehousePG processes the query operators under the resource group assigned to the role that initiated the query. A UDF running in a PL/Container instance runs under the resource group assigned to the PL/Container runtime. The latter is not represented in the `pg_stat_activity` view; WarehousePG does not have any insight into how external components such as PL/Container manage memory in running instances.

Cancelling a Running or Queued Transaction in a Resource Group

There may be cases when you want to cancel a running or queued transaction in a resource group. For example, you may want to remove a query that is waiting in the resource group queue but has not yet been run. Or, you may want to stop a running query that is taking too long to run, or one that is sitting idle in a transaction and taking up resource group transaction slots that are needed by other users.

By default, transactions can remain queued in a resource group indefinitely. If you want WarehousePG to cancel a queued transaction after a specific amount of time, set the server configuration parameter gp_resource_group_queuing_timeout. When this parameter is set to a value (milliseconds) greater than 0, WarehousePG cancels any queued transaction when it has waited longer than the configured timeout.

To manually cancel a running or queued transaction, you must first determine the process id (pid) associated with the transaction. Once you have obtained the process id, you can invoke `pg_cancel_backend()` to end that process, as shown below.

For example, to view the process information associated with all statements currently active or waiting in all resource groups, run the following query. If the query returns no results, then there are no running or queued transactions in any resource group.

```
SELECT rolname, g.rsgname, pid, waiting, state, query, datname
FROM pg_roles, gp_toolkit.gp_resgroup_status g, pg_stat_activity
WHERE pg_roles.rolresgroup=g.groupid
AND pg_stat_activity.usename=pg_roles.rolname;
```

Sample partial query output:

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```
 rolname | rsgname  | pid     | waiting | state  |          query           | datname
---------+----------+---------+---------+--------+------------------------- -+---------
  sammy  | rg_light |  31861  |    f    | idle   | SELECT * FROM mytesttbl; | testdb
  billy  | rg_light |  31905  |    t    | active | SELECT * FROM topten;    | testdb
```

Use this output to identify the process id (`pid`) of the transaction you want to cancel, and then cancel the process. For example, to cancel the pending query identified in the sample output above:

```
SELECT pg_cancel_backend(31905);
```

You can provide an optional message in a second argument to `pg_cancel_backend()` to indicate to the user why the process was cancelled.

> **Note** Do not use an operating system `KILL` command to cancel any WarehousePG process.

Moving a Query to a Different Resource Group

A user with WarehousePG superuser privileges can run the `gp_toolkit.pg_resgroup_move_query()` function to move a running query from one resource group to another, without stopping the query. Use this function to expedite a long-running query by moving it to a resource group with a higher resource allotment or availability.

> **Note** You can move only an active or running query to a new resource group. You cannot move a queued or pending query that is in an idle state due to concurrency or memory limits.

`pg_resgroup_move_query()` requires the process id (pid) of the running query, as well as the name of the resource group to which you want to move the query. The signature of the function follows:

```
pg_resgroup_move_query( pid int4, group_name text );
```

You can obtain the pid of a running query from the `pg_stat_activity` system view as described in Cancelling a Running or Queued Transaction in a Resource Group. Use the `gp_toolkit.gp_resgroup_status` view to list the name, id, and status of each resource group.

When you invoke `pg_resgroup_move_query()`, the query is subject to the limits configured for the destination resource group:

- If the group has already reached its concurrent task limit, WarehousePG queues the query until a slot opens or for `gp_resource_group_queuing_timeout` milliseconds if set.
- If the group has a free slot, `pg_resgroup_move_query()` tries to give slot control away to the target process for up to `gp_resource_group_move_timeout` milliseconds. If target process can't handle movement request until `gp_resource_group_queuing_timeout` exceeds, WarehousePG returns the error: `target process failed to move to a new group`.
- If `pg_resgroup_move_query()` was cancelled, but target process already got all slot controls, segment's processes will not be moved to new group, and target process will hold the slot. Such inconsistent state will be fixed by the end of transaction or by any next command dispatched by target process inside same transaction.
- If the destination resource group does not have enough memory available to service the query's current memory requirements, WarehousePG returns the error: `group <group_name> doesn't have enough memory ...`. In this situation, you may choose to increase the group shared memory allotted to the destination resource group, or perhaps wait a period of time for running queries to complete and then invoke the function again.

After WarehousePG moves the query, there is no way to guarantee that a query currently running in the destination resource group does not exceed the group memory quota. In this situation, one or more running queries in the destination group may fail, including the moved query. Reserve enough resource group global shared memory to minimize the potential for this scenario to occur.

`pg_resgroup_move_query()` moves only the specified query to the destination resource group. WarehousePG assigns subsequent queries that you submit in the session to the original resource group.

Frequently Asked Questions

Why is CPU usage lower than the `CPU_MAX_PERCENT` configured for the resource group?

You may run into this situation when a low number of queries and slices are running in the resource group, and these processes are not utilizing all of the cores on the system.

**My resource group has a `CPU_WEIGHT` equivalent to 40%. Why is the CPU usage never reaching this limit?

The value of `CPU_MAX_PERCENT` might be lower than 40, hence it might be limiting the CPU usage even with idle resources.

Why is the number of running transactions lower than the `CONCURRENCY` limit configured for the resource group?

WarehousePG considers memory availability before running a transaction, and will queue the transaction if there is not enough memory available to serve it. If you use `ALTER RESOURCE GROUP` to increase the `CONCURRENCY` limit for a resource group but do not also adjust memory limits, currently running transactions may be consuming all allotted memory resources for the group. When in this state, WarehousePG queues subsequent transactions in the resource group.

Why is the number of running transactions in the resource group higher than the configured `CONCURRENCY` limit?

This behaviour is expected. There are several reasons why this may happen:

- Resource groups do not enforce resource restrictions on `SET`, `RESET` and `SHOW` commands
- The server configuration parameter `gp_resource_group_bypass` disables the concurrent transaction limit for the resource group so a query can run immediately.
- If the server configuration parameter `gp_resource_group_bypass_catalog_query` is set to true (the default), all queries that read exclusively from system catalogs, or queries that contain in their query text `pg_catalog` schema tables only will not enforce the limits of the resource group.
- Queries whose plan cost is less than the limit `MIN_COST` will be automatically unassigned from their resource group and will not enforce any of the limits set for this.

Why did my query return a "memory limit reached" error?

WarehousePG automatically adjusts transaction and group memory to the new settings when you use `ALTER RESOURCE GROUP` to change a resource group's memory and/or concurrency limits. An "out of memory" error may occur if you recently altered resource group attributes and there is no longer a sufficient amount of memory available for a currently running query.

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My query cannot run due to insufficient memory, resulting in memory leak Out of Memory (OOM).

First, ensure that the resource group is allocating enough memory required by the query by tuning resource group parameters such as `CONCURRENCY` and `MEMORY_QUOTA`. Analyze the type of query, whether there will be a lot of intermediate results using memory. If it does exist, you can set a reasonable `gp_resgroup_memory_query_fixed_mem` to allocate more memory at the session level for this specific query.

After a memory leak OOM the system has a high concurrent load

When the system starts to clean up the sessions left over by the memory leak, the concurrent load of the system is high at this time, and the OOM error message may reappear. Due to the current design, we cannot expedite the cleanup process of the Runaway Session. The solution to this problem is to adjust the `runaway_detector_activation_percent` to 0.85 or 0.8, or even lower, in order to increase the available memory of the segment host.

Some transaction requests only run during a certain period of time, and do not run at other times.

You may change the configuration of resource groups can be changed dynamically at regular intervals to match the requirements of your workload, and customize resource allocation at different times to achieve higher efficiency. For example, change the configuration of resources within a group, add or delete resource groups.

After upgrading WarehousePG, the performance seems to be degraded.

There are many factors that can affect performance degradation. A possible cause is that after upgrading to WarehousePG 7, SWAP is enabled by default and hence affecting your performance. We recommend disabling SWAP and use RAM memory instead, in order to improve running speed and efficiency. If your memory configuration is sufficient, there is no need to use SWAP space. If you decide to use SWAP, be sure you understand how it takes part in the calculation of memory management allocation. See WarehousePG Memory Overview for more information.

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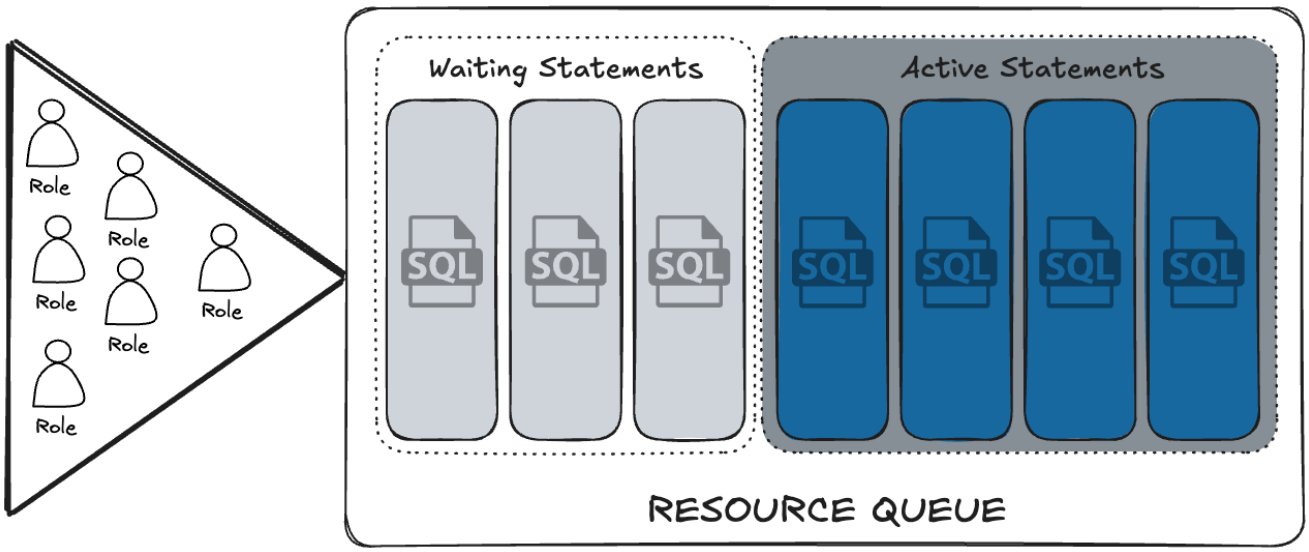
4.10.6.3 Using Resource Queues

Use WarehousePG resource queues to prioritize and allocate resources to queries according to business requirements and to prevent queries from starting when resources are unavailable.

Resource queues are one tool to manage the degree of concurrency in a WarehousePG cluster. Resource queues are database objects that you create with the `CREATE RESOURCE QUEUE` SQL statement. You can use them to manage the number of active queries that may run concurrently, the amount of memory each type of query is allocated, and the relative priority of queries. Resource queues can also guard against queries that would consume too many resources and degrade overall system performance.

Each database role is associated with a single resource queue; multiple roles can share the same resource queue. Roles are assigned to resource queues using the `RESOURCE QUEUE` phrase of the `CREATE ROLE` or `ALTER ROLE` statements. If a resource queue is not specified, the role is associated with the default resource queue, `pg_default`.

When the user submits a query for execution, the query is evaluated against the resource queue's limits. If the query does not cause the queue to exceed its resource limits, then that query will run immediately. If the query causes the queue to exceed its limits (for example, if the maximum number of active statement slots are currently in use), then the query must wait until queue resources are free before it can run. Queries are evaluated on a first in, first out basis. If query prioritization is enabled, the active workload on the system is periodically assessed and processing resources are reallocated according to query priority (see How Priorities Work). Roles with the `SUPERUSER` attribute are exempt from resource queue limits. Superuser queries always run immediately regardless of limits imposed by their assigned resource queue.



Resource queues define classes of queries with similar resource requirements. Administrators should create resource queues for the various types of workloads in their organization. For example, you could create resource queues for the following classes of queries, corresponding to different service level agreements:

- ETL queries
- Reporting queries
- Executive queries

A resource queue has the following characteristics:

`MEMORY_LIMIT` The amount of memory used by all the queries in the queue (per segment). For example, setting `MEMORY_LIMIT` to 2GB on the ETL queue allows ETL queries to use up to 2GB of memory in each segment.

`ACTIVE_STATEMENTS` The number of *slots* for a queue; the maximum concurrency level for a queue. When all slots are used, new queries must wait. Each query uses an equal amount of memory by default.

For example, the `pg_default` resource queue has `ACTIVE_STATEMENTS` = 20.

`PRIORITY` The relative CPU usage for queries. This may be one of the following levels: `LOW`, `MEDIUM`, `HIGH`, `MAX`. The default level is `MEDIUM`. The query prioritization mechanism monitors the CPU usage of all the queries running in the system, and adjusts the CPU usage for each to conform to its priority level. For example, you could set `MAX` priority to the `executive` resource queue and `MEDIUM` to other queues to ensure that executive queries receive a greater share of CPU.

`MAX_COST` Query plan cost limit.

The WarehousePG optimizer assigns a numeric cost to each query. If the cost exceeds the `MAX_COST` value set for the resource queue, the query is rejected as too expensive.

> **Note** GPORCA and the Postgres-based planner utilize different query costing models and may compute different costs for the same query. The WarehousePG resource queue resource management scheme neither differentiates nor aligns costs between GPORCA and the Postgres-based planner; it uses the literal cost value returned from the optimizer to throttle queries.

When resource queue-based resource management is active, use the `MEMORY_LIMIT` and `ACTIVE_STATEMENTS` limits for resource queues rather than configuring cost-based limits. Even when using GPORCA, WarehousePG may fall back to using the Postgres-based planner for certain queries, so using cost-based limits can lead to unexpected results.

The default configuration for a WarehousePG cluster has a single default resource queue named `pg_default`. The `pg_default` resource queue has an `ACTIVE_STATEMENTS` setting of 20, no `MEMORY_LIMIT`, medium `PRIORITY`, and no set `MAX_COST`. This means that all queries are accepted and run immediately, at the same priority and with no memory limitations; however, only twenty queries may run concurrently.

The number of concurrent queries a resource queue allows depends on whether the `MEMORY_LIMIT` parameter is set:

- If no `MEMORY_LIMIT` is set for a resource queue, the amount of memory allocated per query is the value of the statement_mem server configuration parameter. The maximum memory the resource queue can use is the product of `statement_mem` and `ACTIVE_STATEMENTS`.
- When a `MEMORY_LIMIT` is set on a resource queue, the number of queries that the queue can run concurrently is limited by the queue's available memory.

A query admitted to the system is allocated an amount of memory and a query plan tree is generated for it. Each node of the tree is an operator, such as a sort or hash join. Each operator is a separate execution thread and is allocated a fraction of the overall statement memory, at minimum 100KB. If the plan has a large number of operators, the minimum memory required for operators can exceed the available memory and the query will be rejected with an insufficient memory error. Operators determine if they can complete their tasks in the memory allocated, or if they must spill data to disk, in work files. The mechanism that allocates and controls the amount of memory used by each operator is called *memory quota*.

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Not all SQL statements submitted through a resource queue are evaluated against the queue limits. By default only `SELECT`, `SELECT INTO`, `CREATE TABLE AS SELECT`, and `DECLARE CURSOR` statements are evaluated. If the server configuration parameter resource_select_only is set to `off`, then `INSERT`, `UPDATE`, and `DELETE` statements will be evaluated as well.

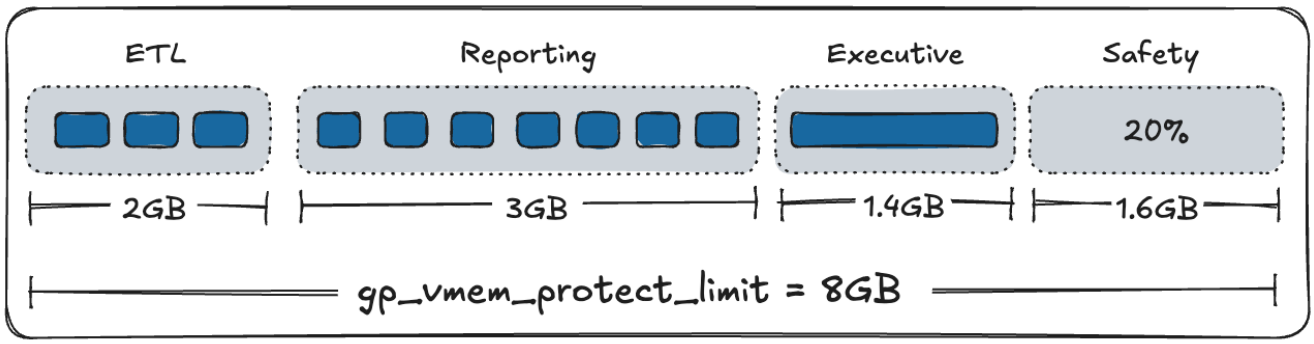
Also, an SQL statement that is run during the execution of an `EXPLAIN ANALYZE` command is excluded from resource queues.

Parent topic: Managing Resources

Resource Queue Example

The default resource queue, `pg_default`, allows a maximum of 20 active queries and allocates the same amount of memory to each. This is generally not adequate resource control for production systems. To ensure that the system meets performance expectations, you can define classes of queries and assign them to resource queues configured to run them with the concurrency, memory, and CPU resources best suited for that class of query.

The following illustration shows an example resource queue configuration for a WarehousePG cluster with `gp_vmem_protect_limit` set to 8GB:



This example has three classes of queries with different characteristics and service level agreements (SLAs). Three resource queues are configured for them. A portion of the segment memory is reserved as a safety margin.

Resource Queue Name	Active Statements	Memory Limit	Memory per Query
ETL	3	2GB	667MB
Reporting	7	3GB	429MB
Executive	1	1.4GB	1.4GB

The total memory allocated to the queues is 6.4GB, or 80% of the total segment memory defined by the `gp_vmem_protect_limit` server configuration parameter. Allowing a safety margin of 20% accommodates some operators and queries that are known to use more memory than they are allocated by the resource queue.

See the CREATE RESOURCE QUEUE, CREATE ROLE, and ALTER ROLE statements in the *WarehousePG Reference Guide* for help with command syntax and detailed reference information.

How Memory Limits Work

Setting `MEMORY_LIMIT` on a resource queue sets the maximum amount of memory that all active queries submitted through the queue can consume for a segment instance. The amount of memory allotted to a query is the queue memory limit divided by the active statement limit. (Use the memory limits in conjunction with statement-based queues rather than cost-based queues.) For example, if a queue has a memory limit of 2000MB and an active statement limit of 10, each query submitted through the queue is allotted 200MB of memory by default. The default memory allotment can be overridden on a per-query basis using the `statement_mem` server configuration parameter (up to the queue memory limit). Once a query has started running, it holds its allotted memory in the queue until it completes, even if during execution it actually consumes less than its allotted amount of memory.

You can use the `statement_mem` server configuration parameter to override memory limits set by the current resource queue. At the session level, you can increase `statement_mem` up to the resource queue's `MEMORY_LIMIT`. This will allow an individual query to use all of the memory allocated for the entire queue without affecting other resource queues.

The value of `statement_mem` is capped using the `max_statement_mem` configuration parameter (a superuser parameter). For a query in a resource queue with `MEMORY_LIMIT` set, the maximum value for `statement_mem` is `min(MEMORY_LIMIT, max_statement_mem)`. When a query is admitted, the memory allocated to it is subtracted from `MEMORY_LIMIT`. If `MEMORY_LIMIT` is exhausted, new queries in the same resource queue must wait. This happens even if `ACTIVE_STATEMENTS` has not yet been reached. Note that this can happen only when `statement_mem` is used to override the memory allocated by the resource queue.

For example, consider a resource queue named `adhoc` with the following settings:

- `MEMORY_LIMIT` is 1.5GB
- `ACTIVE_STATEMENTS` is 3

By default each statement submitted to the queue is allocated 500MB of memory. Now consider the following series of events:

1. User `ADHOC_1` submits query `Q1`, overriding `STATEMENT_MEM` to 800MB. The `Q1` statement is admitted into the system.
2. User `ADHOC_2` submits query `Q2`, using the default 500MB.
3. With `Q1` and `Q2` still running, user `ADHOC3` submits query `Q3`, using the default 500MB.

Queries `Q1` and `Q2` have used 1300MB of the queue's 1500MB. Therefore, `Q3` must wait for `Q1` or `Q2` to complete before it can run.

If `MEMORY_LIMIT` is not set on a queue, queries are admitted until all of the `ACTIVE_STATEMENTS` slots are in use, and each query can set an arbitrarily high `statement_mem`. This could lead to a resource queue using unbounded amounts of memory.

For more information on configuring memory limits on a resource queue, and other memory utilization controls, see Creating Queues with Memory Limits.

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statement_mem and Low Memory Queries

A low `statement_mem` setting (for example, in the 1-3MB range) has been shown to increase the performance of queries with low memory requirements. Use the `statement_mem` server configuration parameter to override the setting on a per-query basis. For example:

```
SET statement_mem='2MB';
```

How Priorities Work

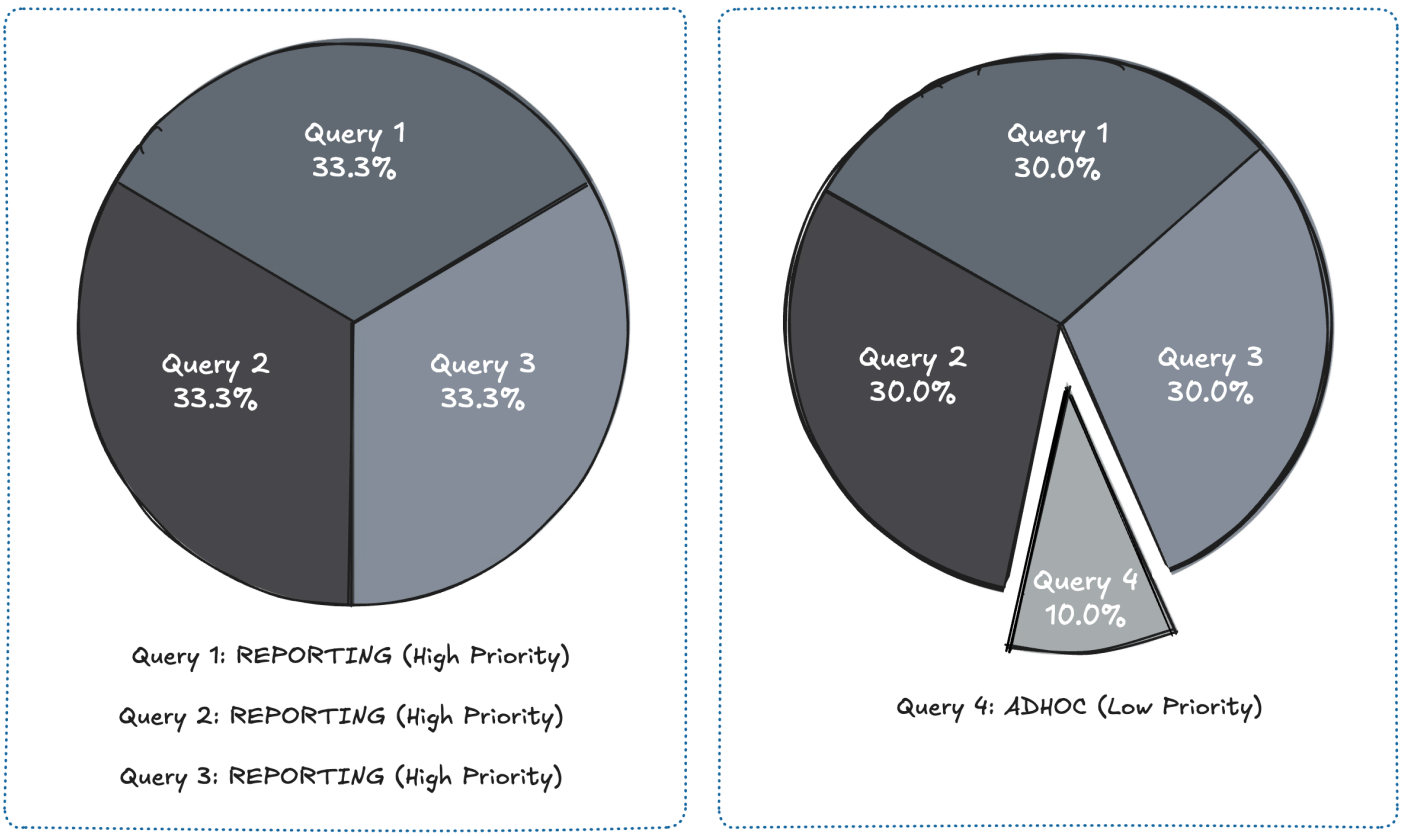
The `PRIORITY` setting for a resource queue differs from the `MEMORY_LIMIT` and `ACTIVE_STATEMENTS` settings, which determine whether a query will be admitted to the queue and eventually run. The `PRIORITY` setting applies to queries after they become active. Active queries share available CPU resources as determined by the priority settings for its resource queue. When a statement from a high-priority queue enters the group of actively running statements, it may claim a greater share of the available CPU, reducing the share allocated to already-running statements in queues with a lesser priority setting.

The comparative size or complexity of the queries does not affect the allotment of CPU. If a simple, low-cost query is running simultaneously with a large, complex query, and their priority settings are the same, they will be allocated the same share of available CPU resources. When a new query becomes active, the CPU shares will be recalculated, but queries of equal priority will still have equal amounts of CPU.

For example, an administrator creates three resource queues: *adhoc* for ongoing queries submitted by business analysts, *reporting* for scheduled reporting jobs, and *executive* for queries submitted by executive user roles. The administrator wants to ensure that scheduled reporting jobs are not heavily affected by unpredictable resource demands from ad-hoc analyst queries. Also, the administrator wants to make sure that queries submitted by executive roles are allotted a significant share of CPU. Accordingly, the resource queue priorities are set as shown:

- *adhoc* — Low priority
- *reporting* — High priority
- *executive* — Maximum priority

At runtime, the CPU share of active statements is determined by these priority settings. If queries 1, 2 and 3 from the **reporting** queue are running simultaneously, they have equal shares of CPU. When an **ad-hoc** query becomes active, it claims a smaller share of CPU. The exact share used by the reporting queries is adjusted, but remains equal due to their equal priority setting:



Note The percentages shown in these illustrations are approximate. CPU usage between high, low and maximum priority queues is not always calculated in precisely these proportions.

When an executive query enters the group of running statements, CPU usage is adjusted to account for its maximum priority setting. It may be a simple query compared to the analyst and reporting queries, but until it is completed, it will claim the largest share of CPU.

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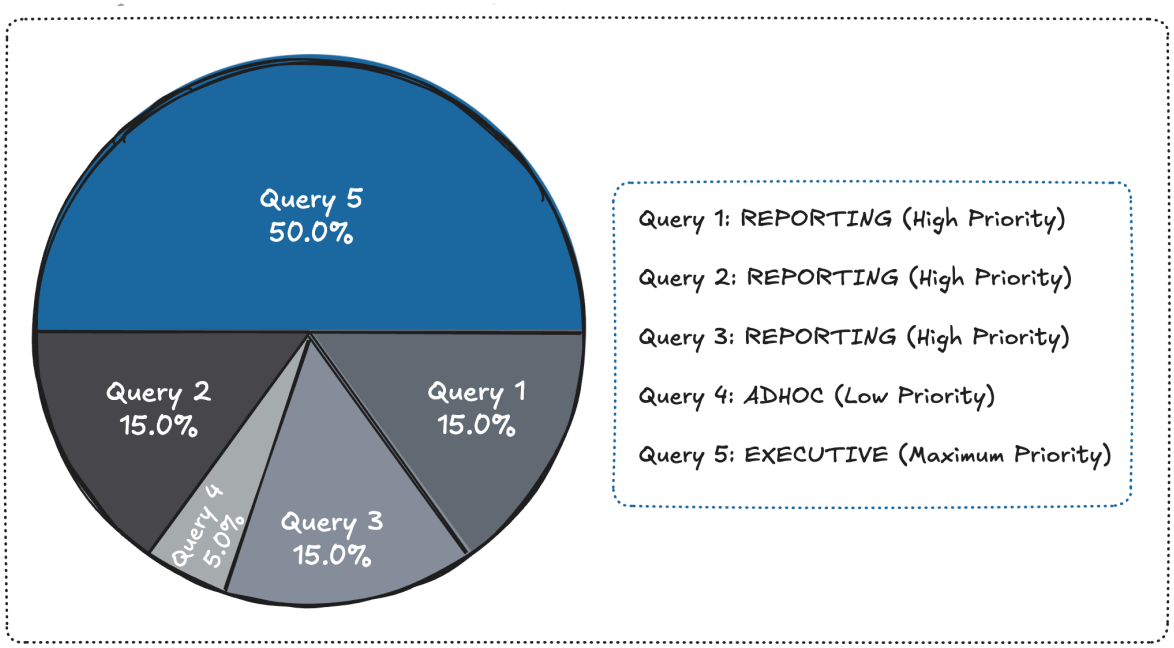

For more information about commands to set priorities, see Setting Priority Levels.

Enabling Resource Queues

When you install WarehousePG, no resource management policy is enabled by default. To use resource queues, set the gp_resource_manager server configuration parameter:

1. Set the `gp_resource_manager` server configuration parameter to the value `"queue"`

   ```
   gpconfig -c gp_resource_manager -v "queue"
   ```

2. Restart WarehousePG:

   ```
   gpstop
   gpstart
   ```

Configuring Resource Queues

Before you create any resource groups, learn about the different resouce queue server configuration parameters and their usage. See Server Configuration Parameters for more information.

1. General configuration

   - `max_resource_queues` - Sets the maximum number of resource queues.
   - `max_resource_portals_per_transaction` - Sets the maximum number of simultaneously open cursors allowed per transaction. Note that an open cursor will hold an active query slot in a resource queue.
   - `resource_select_only` - If set to *on*, then `SELECT`, `SELECT INTO`, `CREATE TABLE AS``SELECT`, and `DECLARE CURSOR` commands are evaluated. If set to *off* `INSERT`, `UPDATE`, and `DELETE` commands will be evaluated as well.
   - `resource_cleanup_gangs_on_wait` - Cleans up idle segment worker processes before taking a slot in the resource queue.
   - `stats_queue_level` - Enables statistics collection on resource queue usage, which can then be viewed by querying the pg_stat_resqueues system view.

2. Memory utilization

   - `gp_resqueue_memory_policy` - Enables WarehousePG memory management features.

     In WarehousePG 4.2 and later, the distribution algorithm `eager_free` takes advantage of the fact that not all operators run at the same time. The query plan is divided into stages and WarehousePG eagerly frees memory allocated to a previous stage at the end of that stage's execution, then allocates the eagerly freed memory to the new stage.

     When set to `none`, memory management is the same as in WarehousePG releases prior to 4.1. When set to `auto`, query memory usage is controlled by `statement_mem` and resource queue memory limits.

   - `statement_mem` and `max_statement_mem` - Used to allocate memory to a particular query at runtime (override the default allocation assigned by the resource queue). `max_statement_mem` is set by database superusers to prevent regular database users from over-allocation.

   - `gp_vmem_protect_limit` - Sets the upper boundary that all query processes can consume and should not exceed the amount of physical memory of a segment host. When a segment host reaches this limit during query execution, the queries that cause the limit to be exceeded will be cancelled.

   - `gp_vmem_idle_resource_timeout` and `gp_vmem_protect_segworker_cache_limit` - used to free memory on segment hosts held by idle database processes. Administrators may want to adjust these settings on systems with lots of concurrency.

   - `shared_buffers` - Sets the amount of memory a WarehousePG server instance uses for shared memory buffers. This setting must be at least 128 kilobytes and at least 16 kilobytes times `max_connections`. The value must not exceed the operating system shared memory maximum allocation request size, `shmmax` on Linux. See the *WarehousePG Installation Guide* for recommended OS memory settings for your platform.

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3. Query prioritization. Note that the following parameters are all *local* parameters, meaning they must be set in the `postgresql.conf` files of the coordinator and all segments:

    - `gp_resqueue_priority` - The query prioritization feature is enabled by default.

    - `gp_resqueue_priority_sweeper_interval` - Sets the interval at which CPU usage is recalculated for all active statements. The default value for this parameter should be sufficient for typical database operations.

    - `gp_resqueue_priority_cpucores_per_segment` - Specifies the number of CPU cores allocated per segment instance on a segment host. If the segment is configured with primary-mirror segment instance pairs, use the number of primary segment instances on the host in the calculation. The default value is 4 for the coordinator and segment hosts.

      Each WarehousePG host checks its own `postgresql.conf` file for the value of this parameter. This parameter also affects the coordinator host, where it should be set to a value reflecting the higher ratio of CPU cores. For example, on a cluster that has 10 CPU cores per segment host and 4 primary segments per host, you would specify the following values for `gp_resqueue_priority_cpucores_per_segment`:

        - 10 on the coordinator and standby coordinator hosts. Typically, only a single coordinator segment instance runs on the coordinator host.
        - 2.5 on each segment host (10 cores divided by 4 primary segments).
          If the parameter value is not set correctly, either the CPU might not be fully utilized, or query prioritization might not work as expected. For example, if the WarehousePG cluster has fewer than one segment instance per CPU core on your segment hosts, make sure that you adjust this value accordingly.

      Actual CPU core utilization is based on the ability of WarehousePG to parallelize a query and the resources required to run the query.

      > **Note** Include any CPU core that is available to the operating system in the number of CPU cores, including virtual CPU cores.

Use the `gpconfig` utility to view or change any of the resource management parameter values. For example, to see the setting of a particular parameter:

```
gpconfig --show gp_vmem_protect_limit
```

To set one value on all segment instances and a different value on the coordinator:

```
gpconfig -c gp_resqueue_priority_cpucores_per_segment -v 2 -m 8
```

Restart WarehousePG to make the configuration changes effective:

```
gpstop -r
```

Creating Resource Queues

When you create a resource queue for a role, you provide a name, set an active query limit, and optionally a query priority for the resource queue. Use theCREATE RESOURCE QUEUE command to create new resource queues.

Creating Queues with an Active Query Limit

Resource queues with an `ACTIVE_STATEMENTS` setting limit the number of queries that can be run by roles assigned to that queue. For example, to create a resource queue named*adhoc* with an active query limit of three:

```
CREATE RESOURCE QUEUE adhoc WITH (ACTIVE_STATEMENTS=3);
```

This means that for all roles assigned to the *adhoc* resource queue, only three active queries can be running on the system at any given time. If this queue has three queries running, and a fourth query is submitted by a role in that queue, that query must wait until a slot is free before it can run.

Creating Queues with Memory Limits

Resource queues with a `MEMORY_LIMIT` setting control the amount of memory for all the queries submitted through the queue. The total memory should not exceed the physical memory available per-segment. Set `MEMORY_LIMIT` to 90% of memory available on a per-segment basis. For example, if a host has 48 GB of physical memory and 6 segment instances, then the memory available per segment instance is 8 GB. You can calculate the recommended `MEMORY_LIMIT` for a single queue as 0.90*8=7.2 GB. If there are multiple queues created on the system, their total memory limits must also add up to 7.2 GB.

When used in conjunction with `ACTIVE_STATEMENTS`, the default amount of memory allotted per query is: `MEMORY_LIMIT / ACTIVE_STATEMENTS`. When used in conjunction with `MAX_COST`, the default amount of memory allotted per query is: `MEMORY_LIMIT * (query_cost / MAX_COST)`. Use `MEMORY_LIMIT` in conjunction with `ACTIVE_STATEMENTS` rather than with `MAX_COST`.

For example, to create a resource queue with an active query limit of 10 and a total memory limit of 2000MB (each query will be allocated 200MB of segment host memory at execution time):

```
CREATE RESOURCE QUEUE myqueue WITH (ACTIVE_STATEMENTS=20,
MEMORY_LIMIT='2000MB');
```

The default memory allotment can be overridden on a per-query basis using the `statement_mem` server configuration parameter, provided that `MEMORY_LIMIT` or `max_statement_mem` is not exceeded. For example, to allocate more memory to a particular query:

```
SET statement_mem='2GB';
SELECT * FROM my_big_table WHERE column='value' ORDER BY id;
RESET statement_mem;
```

As a general guideline, `MEMORY_LIMIT` for all of your resource queues should not exceed the amount of physical memory of a segment host. If workloads are staggered over multiple queues, it may be OK to oversubscribe memory allocations, keeping in mind that queries may be cancelled during execution if the segment host memory limit (`gp_vmem_protect_limit`) is exceeded.

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Setting Priority Levels

To control a resource queue's consumption of available CPU resources, an administrator can assign an appropriate priority level. When high concurrency causes contention for CPU resources, queries and statements associated with a high-priority resource queue will claim a larger share of available CPU than lower priority queries and statements.

Priority settings are created or altered using the `WITH` parameter of the commands `CREATE RESOURCE QUEUE` and `ALTER RESOURCE QUEUE`. For example, to specify priority settings for the *adhoc* and *reporting* queues, an administrator would use the following commands:

```
ALTER RESOURCE QUEUE adhoc WITH (PRIORITY=LOW);
ALTER RESOURCE QUEUE reporting WITH (PRIORITY=HIGH);
```

To create the *executive* queue with maximum priority, an administrator would use the following command:

```
CREATE RESOURCE QUEUE executive WITH (ACTIVE_STATEMENTS=3, PRIORITY=MAX);
```

When the query prioritization feature is enabled, resource queues are given a `MEDIUM` priority by default if not explicitly assigned. For more information on how priority settings are evaluated at runtime, see How Priorities Work.

> **Important** In order for resource queue priority levels to be enforced on the active query workload, you must enable the query prioritization feature by setting the associated server configuration parameters. SeeConfiguring Resource Queues.

Assigning Roles to a Resource Queue

Once a resource queue is created, you must assign roles (users) to their appropriate resource queue. If roles are not explicitly assigned to a resource queue, they will go to the default resource queue `pg_default`. The default resource queue has an active statement limit of 20, no cost limit, and a medium priority setting.

Use the `ALTER ROLE` or `CREATE ROLE` commands to assign a role to a resource queue. For example:

```
ALTER ROLE `name` RESOURCE QUEUE `queue_name`;
CREATE ROLE `name` WITH LOGIN RESOURCE QUEUE `queue_name`;
```

A role can only be assigned to one resource queue at any given time, so you can use the `ALTER ROLE` command to initially assign or change a role's resource queue.

Resource queues must be assigned on a user-by-user basis. If you have a role hierarchy (for example, a group-level role) then assigning a resource queue to the group does not propagate down to the users in that group.

Superusers are always exempt from resource queue limits. Superuser queries will always run regardless of the limits set on their assigned queue.

Removing a Role from a Resource Queue

All users *must* be assigned to a resource queue. If not explicitly assigned to a particular queue, users will go into the default resource queue, `pg_default`. If you wish to remove a role from a resource queue and put them in the default queue, change the role's queue assignment to `none`. For example:

```
ALTER ROLE `role_name` RESOURCE QUEUE none;
```

Modifying Resource Queues

After a resource queue has been created, you can change or reset the queue limits using the `ALTER RESOURCE QUEUE` command. You can remove a resource queue using the `DROP RESOURCE QUEUE` command. To change the roles (users) assigned to a resource queue, Assigning Roles to a Resource Queue.

Altering a Resource Queue

The `ALTER RESOURCE QUEUE` command changes the limits of a resource queue. To change the limits of a resource queue, specify the new values you want for the queue. For example:

```
ALTER RESOURCE QUEUE <adhoc> WITH (ACTIVE_STATEMENTS=5);
ALTER RESOURCE QUEUE <exec> WITH (PRIORITY=MAX);
```

To reset active statements or memory limit to no limit, enter a value of `-1`. To reset the maximum query cost to no limit, enter a value of `-1.0`. For example:

```
ALTER RESOURCE QUEUE <adhoc> WITH (MAX_COST=-1.0, MEMORY_LIMIT='2GB');
```

You can use the `ALTER RESOURCE QUEUE` command to change the priority of queries associated with a resource queue. For example, to set a queue to the minimum priority level:

```
ALTER RESOURCE QUEUE <webuser> WITH (PRIORITY=MIN);
```

Dropping a Resource Queue

The `DROP RESOURCE QUEUE` command drops a resource queue. To drop a resource queue, the queue cannot have any roles assigned to it, nor can it have any statements waiting in the queue. SeeRemoving a Role from a Resource Queue and Clearing a Waiting Statement From a Resource Queue for instructions on emptying a resource queue. To drop a resource queue:

```
DROP RESOURCE QUEUE <name>;
```

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Monitoring Resource Queue Status

Monitoring resource queue status involves the following tasks:

Viewing Queued Statements and Resource Queue Status

The gp_resqueue_status `gp_toolkit` view allows administrators to see status and activity for a resource queue. It shows how many queries are waiting to run and how many queries are currently active in the system from a particular resource queue. To see the resource queues created in the system, their limit attributes, and their current status:

```
SELECT * FROM gp_toolkit.gp_resqueue_status;
```

Viewing Resource Queue Statistics

If you want to track statistics and performance of resource queues over time, you can enable statistics collecting for resource queues. This is done by setting the following server configuration parameter in your coordinator `postgresql.conf` file:

```
stats_queue_level = on
```

Once this is enabled, you can use the `pg_stat_resqueue` system view to see the statistics collected on resource queue usage. Note that enabling this feature does incur slight performance overhead, as each query submitted through a resource queue must be tracked. It may be useful to enable statistics collecting on resource queues for initial diagnostics and administrative planning, and then deactivate the feature for continued use.

See the Statistics Collector section in the PostgreSQL documentation for more information about collecting statistics in WarehousePG.

Viewing the Roles Assigned to a Resource Queue

To see the roles assigned to a resource queue, perform the following query of the `pg_roles` and The gp_resqueue_status `gp_toolkit` system catalog tables:

```
SELECT rolname, rsqname FROM pg_roles,
       gp_toolkit.gp_resqueue_status
WHERE pg_roles.rolresqueue=gp_toolkit.gp_resqueue_status.queueid;
```

You may want to create a view of this query to simplify future inquiries. For example:

```
CREATE VIEW role2queue AS
SELECT rolname, rsqname FROM pg_roles, pg_resqueue
WHERE pg_roles.rolresqueue=gp_toolkit.gp_resqueue_status.queueid;
```

Then you can just query the view:

```
SELECT * FROM role2queue;
```

Viewing the Waiting Queries for a Resource Queue

When a slot is in use for a resource queue, it is recorded in the `pg_locks` system catalog table. This is where you can see all of the currently active and waiting queries for all resource queues. To check that statements are being queued (even statements that are not waiting), you can also use the gp_locks_on_resqueue `gp_toolkit` view. For example:

```
SELECT * FROM gp_toolkit.gp_locks_on_resqueue WHERE lorwaiting='true';
```

If this query returns no results, then that means there are currently no statements waiting in a resource queue.

Clearing a Waiting Statement From a Resource Queue

In some cases, you may want to clear a waiting statement from a resource queue. For example, you may want to remove a query that is waiting in the queue but has not been run yet. You may also want to stop a query that has been started if it is taking too long to run, or if it is sitting idle in a transaction and taking up resource queue slots that are needed by other users. To do this, you must first identify the statement you want to clear, determine its process id (pid), and then, use `pg_cancel_backend` with the process id to end that process, as shown below. An optional message to the process can be passed as the second parameter, to indicate to the user why the process was cancelled.

For example, to see process information about all statements currently active or waiting in all resource queues, run the following query:

```
SELECT rolname, rsqname, pg_locks.pid as pid, granted, state,
       query, datname
FROM pg_roles, gp_toolkit.gp_resqueue_status, pg_locks,
     pg_stat_activity
WHERE pg_roles.rolresqueue=pg_locks.objid
AND pg_locks.objid=gp_toolkit.gp_resqueue_status.queueid
AND pg_stat_activity.pid=pg_locks.pid
AND pg_stat_activity.usename=pg_roles.rolname;
```

If this query returns no results, then that means there are currently no statements in a resource queue. A sample of a resource queue with two statements in it looks something like this:

```
rolname | rsqname |  pid  | granted | state  |         query          | datname
--------+---------+-------+---------+--------+------------------------+---------
  sammy | webuser | 31861 | t       | idle   | SELECT * FROM testtbl; | namesdb
  daria | webuser | 31905 | f       | active | SELECT * FROM topten;  | namesdb
```

Use this output to identify the process id (pid) of the statement you want to clear from the resource queue. To clear the statement, you would then open a terminal window (as the `gpadmin` database superuser or as root) on the coordinator host and cancel the corresponding process. For example:

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```
pg_cancel_backend(31905)
```

> **Important** Do not use the operating system `KILL` command.

Viewing the Priority of Active Statements

The *gp_toolkit* administrative schema has a view called gp_resq_priority_statement, which lists all statements currently being run and provides the priority, session ID, and other information.

This view is only available through the `gp_toolkit` administrative schema. See the *WarehousePG Reference Guide* for more information.

Resetting the Priority of an Active Statement

Superusers can adjust the priority of a statement currently being run using the built-in function `gp_adjust_priority(session_id, statement_count, priority)`. Using this function, superusers can raise or lower the priority of any query. For example:

```
SELECT gp_adjust_priority(752, 24905, 'HIGH')`
```

To obtain the session ID and statement count parameters required by this function, superusers can use the `gp_toolkit` administrative schema view gp_resq_priority_statement. From the view, use these values for the function parameters.

- The value of the `rqpsession` column for the `session_id` parameter
- The value of the `rqpcommand` column for the `statement_count` parameter
- The value of `rqppriority` column is the current priority. You can specify a string value of `MAX`, `HIGH`, `MEDIUM`, or `LOW` as the `priority`.

> **Note** The `gp_adjust_priority()` function affects only the specified statement. Subsequent statements in the same resource queue are run using the queue's normally assigned priority.

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4.10.7 Investigating a Performance Problem

This section provides guidelines for identifying and troubleshooting performance problems in a WarehousePG cluster.

This topic lists steps you can take to help identify the cause of a performance problem. If the problem affects a particular workload or query, you can focus on tuning that particular workload. If the performance problem is system-wide, then hardware problems, system failures, or resource contention may be the cause.

Parent topic: Managing Performance

Checking System State

Use the `gpstate` utility to identify failed segments. A WarehousePG cluster will incur performance degradation when segment instances are down because other hosts must pick up the processing responsibilities of the down segments.

Failed segments can indicate a hardware failure, such as a failed disk drive or network card. WarehousePG provides the hardware verification tool `gpcheckperf` to help identify the segment hosts with hardware issues.

Checking Database Activity

- Checking for Active Sessions (Workload)
- Checking for Locks (Contention)
- Checking Query Status and System Utilization

Checking for Active Sessions (Workload)

The *pg_stat_activity* system catalog view shows one row per server process; it shows the database OID, database name, process ID, user OID, user name, current query, time at which the current query began execution, time at which the process was started, client address, and port number. To obtain the most information about the current system workload, query this view as the database superuser. For example:

```
SELECT * FROM pg_stat_activity;
```

Note that the information does not update instantaneously.

Checking for Locks (Contention)

The *pg_locks* system catalog view allows you to see information about outstanding locks. If a transaction is holding a lock on an object, any other queries must wait for that lock to be released before they can continue. This may appear to the user as if a query is hanging.

Examine *pg_locks* for ungranted locks to help identify contention between database client sessions. *pg_locks* provides a global view of all locks in the database system, not only those relevant to the current database. You can join its relation column against `pg_class.oid` to identify locked relations (such as tables), but this works correctly only for relations in the current database. You can join the `pid` column to the `pg_stat_activity.pid` to see more information about the session holding or waiting to hold a lock. For example:

```
SELECT locktype, database, c.relname, l.relation,
l.transactionid, l.pid, l.mode, l.granted,
a.query
        FROM pg_locks l, pg_class c, pg_stat_activity a
        WHERE l.relation=c.oid AND l.pid=a.pid
        ORDER BY c.relname;
```

If you use resource groups, queries that are waiting will also show in *pg_locks*. To see how many queries are waiting to run in a resource group, use the *gp_resgroup_status* system catalog view. For example:

```
SELECT * FROM gp_toolkit.gp_resgroup_status;
```

Similarly, if you use resource queues, queries that are waiting in a queue also show in *pg_locks*. To see how many queries are waiting to run from a resource queue, use the *gp_resqueue_status* system catalog view. For example:

```
SELECT * FROM gp_toolkit.gp_resqueue_status;
```

Checking Query Status and System Utilization

You can use system monitoring utilities such as `ps`, `top`, `iostat`, `vmstat`, `netstat` and so on to monitor database activity on the hosts in your WarehousePG cluster. These tools can help identify WarehousePG processes (`postgres` processes) currently running on the system and the most resource intensive tasks with regards to CPU, memory, disk I/O, or network activity. Look at these system statistics to identify queries that degrade database performance by overloading the system and consuming excessive resources. WarehousePG's management tool `gpssh` allows you to run these system monitoring commands on several hosts simultaneously.

You can create and use the WarehousePG *session_level_memory_consumption* view that provides information about the current memory utilization and idle time for sessions that are running queries on WarehousePG. For information about the view, see Viewing Session Memory Usage Information.

Troubleshooting Problem Queries

If a query performs poorly, look at its query plan to help identify problems. The `EXPLAIN` command shows the query plan for a given query. See Query Profiling for more information about reading query plans and identifying problems.

When an out of memory event occurs during query execution, the WarehousePG memory accounting framework reports detailed memory consumption of every query running at the time of the event. The information is written to the WarehousePG segment logs.

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Investigating Error Messages

WarehousePG log messages are written to files in the `log` directory within the coordinator's or segment's data directory. Because the coordinator log file contains the most information, you should always check it first. Log files roll over daily and use the naming convention: `gpdb- *YYYY - MM - DD_hhmmss.csv*`. To locate the log files on the coordinator host:

```
$ cd $COORDINATOR_DATA_DIRECTORY/log
```

Log lines have the format of:

```
<timestamp> | <user> | <database> | <statement_id> | <con#><cmd#>
|:-<LOG_LEVEL>: <log_message>
```

You may want to focus your search for `WARNING`, `ERROR`, `FATAL` or `PANIC` log level messages. You can use the WarehousePG utility `gplogfilter` to search through WarehousePG log files. For example, when you run the following command on the coordinator host, it checks for problem log messages in the standard logging locations:

```
$ gplogfilter -t
```

To search for related log entries in the segment log files, you can run `gplogfilter` on the segment hosts using `gpssh`. You can identify corresponding log entries by the `*statement_id*` or `*con #*` (session identifier). For example, to search for log messages in the segment log files containing the string `con6` and save output to a file:

```
gpssh -f seg_hosts_file -e 'source
/usr/edb/whpg7/greenplum_path.sh ; gplogfilter -f
con6 /gpdata/*/log/gpdb*.csv' > seglog.out
```

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4.11 Retrieving Query Results with a Parallel Retrieve Cursor

A *parallel retrieve cursor* is an enhanced cursor implementation that you can use to create a special kind of cursor on the WarehousePG coordinator node, and retrieve query results, on demand and in parallel, directly from the WarehousePG segments.

About Parallel Retrieve Cursors

You use a cursor to retrieve a smaller number of rows at a time from a larger query. When you declare a parallel retrieve cursor, the WarehousePG Database Query Dispatcher (QD) dispatches the query plan to each Query Executor (QE), and creates an *endpoint* on each QE before it executes the query. An endpoint is a query result source for a parallel retrieve cursor on a specific QE. Instead of returning the query result to the QD, an endpoint retains the query result for retrieval via a different process: a direct connection to the endpoint. You open a special retrieve mode connection, called a *retrieve session*, and use the new `RETRIEVE` SQL command to retrieve query results from each parallel retrieve cursor endpoint. You can retrieve from parallel retrieve cursor endpoints on demand and in parallel.

You can use the following functions and views to examine and manage parallel retrieve cursors and endpoints:

Function, View Name	Description
gp_get_endpoints() gp_endpoints	List the endpoints associated with all active parallel retrieve cursors declared by the current user in the current database. When the WarehousePG superuser invokes this function, it returns a list of all endpoints for all parallel retrieve cursors declared by all users in the current database.
gp_get_session_endpoints() gp_session_endpoints	List the endpoints associated with all parallel retrieve cursors declared in the current session for the current user.
gp_get_segment_endpoints() gp_segment_endpoints	List the endpoints created in the QE for all active parallel retrieve cursors declared by the current user. When the WarehousePG superuser accesses this view, it returns a list of all endpoints on the QE created for all parallel retrieve cursors declared by all users.
gp_wait_parallel_retrieve_cursor(cursorname text, timeout_sec int4)	Return cursor status or block and wait for results to be retrieved from all endpoints associated with the specified parallel retrieve cursor.

> **Note:** Each of these functions and views is located in the `pg_catalog` schema, and each `RETURNS TABLE`.

Using a Parallel Retrieve Cursor

You will perform the following tasks when you use a WarehousePG parallel retrieve cursor to read query results in parallel from WarehousePG segments:

1. Declare the parallel retrieve cursor.
2. List the endpoints of the parallel retrieve cursor.
3. Open a retrieve connection to each endpoint.
4. Retrieve data from each endpoint.
5. Wait for data retrieval to complete.
6. Handle data retrieval errors.
7. Close the parallel retrieve cursor.

In addition to the above, you may optionally choose to List all parallel retrieve cursors in the system or List segment-specific retrieve session information.

Declaring a Parallel Retrieve Cursor

You DECLARE a cursor to retrieve a smaller number of rows at a time from a larger query. When you declare a parallel retrieve cursor, you can retrieve the query results directly from the WarehousePG segments.

The syntax for declaring a parallel retrieve cursor is similar to that of declaring a regular cursor; you must additionally include the `PARALLEL RETRIEVE` keywords in the command. You can declare a parallel retrieve cursor only within a transaction, and the cursor name that you specify when you declare the cursor must be unique within the transaction.

For example, the following commands begin a transaction and declare a parallel retrieve cursor named `prc1` to retrieve the results from a specific query:

```
BEGIN;
DECLARE prc1 PARALLEL RETRIEVE CURSOR FOR
<i>query</i>;
```

WarehousePG creates the endpoint(s) on the QD or QEs, depending on the *query* parameters:

- WarehousePG creates an endpoint on the QD when the query results must be gathered by the coordinator. For example, this `DECLARE` statement requires that the coordinator gather the query results:

  ```
  DECLARE c1 PARALLEL RETRIEVE CURSOR FOR SELECT * FROM t1 ORDER BY
  a;
  ```

  > **Note:** You may choose to run the `EXPLAIN` command on the parallel retrieve cursor query to identify when motion is involved. Consider using a regular cursor for such queries.

- When the query involves direct dispatch to a segment (the query is filtered on the distribution key), WarehousePG creates the endpoint(s) on specific segment host(s). For example, this `DECLARE` statement may result in the creation of single endpoint:

  ```
  DECLARE c2 PARALLEL RETRIEVE CURSOR FOR SELECT * FROM t1 WHERE
  a=1;
  ```

- WarehousePG creates the endpoints on all segment hosts when all hosts contribute to the query results. This example `DECLARE` statement results in all segments contributing query results:

  ```
  DECLARE c3 PARALLEL RETRIEVE CURSOR FOR SELECT * FROM
  t1;
  ```

The `DECLARE` command returns when the endpoints are ready and query execution has begun.

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Listing a Parallel Retrieve Cursor's Endpoints

You can obtain the information that you need to initiate a retrieve connection to an endpoint by invoking the `gp_get_endpoints()` function or examining the `gp_endpoints` view in a session on the WarehousePG coordinator host:

```
SELECT * FROM
gp_get_endpoints();
SELECT * FROM gp_endpoints;
```

These commands return the list of endpoints in a table with the following columns:

Column Name	Description
gp_segment_id	The QE's endpoint `gp_segment_id`.
auth_token	The authentication token for a retrieve session.
cursorname	The name of the parallel retrieve cursor.
sessionid	The identifier of the session in which the parallel retrieve cursor was created.
hostname	The name of the host from which to retrieve the data for the endpoint.
port	The port number from which to retrieve the data for the endpoint.
username	The name of the current user; *you must initiate the retrieve session as this user.*
state	The state of the endpoint; the valid states are: READY: The endpoint is ready to be retrieved. ATTACHED: The endpoint is attached to a retrieve connection. RETRIEVING: A retrieve session is retrieving data from the endpoint at this moment. FINISHED: The endpoint has been fully retrieved. RELEASED: Due to an error, the endpoint has been released and the connection closed.
endpointname	The endpoint identifier; you provide this identifier to the `RETRIEVE` command.

Refer to the gp_endpoints view reference page for more information about the endpoint attributes returned by these commands.

You can similarly invoke the `gp_get_session_endpoints()` function or examine the `gp_session_endpoints` view to list the endpoints created for the parallel retrieve cursors declared in the current session and by the current user.

Opening a Retrieve Session

After you declare a parallel retrieve cursor, you can open a retrieve session to each endpoint. Only a single retrieve session may be open to an endpoint at any given time.

> **Note:** A retrieve session is independent of the parallel retrieve cursor itself and the endpoints.

Retrieve session authentication does not depend on the `pg_hba.conf` file, but rather on an authentication token (`auth_token`) generated by WarehousePG.

> **Note:** Because WarehousePG skips `pg_hba.conf`-controlled authentication for a retrieve session, for security purposes you may invoke only the `RETRIEVE` command in the session.

When you initiate a retrieve session to an endpoint:

- The user that you specify for the retrieve session must be the user that declared the parallel retrieve cursor (the `username` returned by `gp_endpoints`). This user must have WarehousePG login privileges.
- You specify the `hostname` and `port` returned by `gp_endpoints` for the endpoint.
- You authenticate the retrieve session by specifying the `auth_token` returned for the endpoint via the `PGPASSWORD` environment variable, or when prompted for the retrieve session `Password`.
- You must specify the gp_retrieve_conn server configuration parameter on the connection request, and set the value to `true`.

For example, if you are initiating a retrieve session via `psql`:

```
PGOPTIONS='-c gp_retrieve_conn=true' psql -h <hostname> -p <port> -U <username> -d <dbname>
```

To distinguish a retrieve session from other sessions running on a segment host, WarehousePG includes the `[retrieve]` tag on the `ps` command output display for the process.

Retrieving Data From the Endpoint

Once you establish a retrieve session, you retrieve the tuples associated with a query result on that endpoint using theRETRIEVE command.

You can specify a (positive) number of rows to retrieve, or `ALL` rows:

```
RETRIEVE 7 FROM ENDPOINT
prc10000003300000003;
RETRIEVE ALL FROM ENDPOINT
prc10000003300000003;
```

WarehousePG returns an empty set if there are no more rows to retrieve from the endpoint.

> **Note:** You can retrieve from multiple parallel retrieve cursors from the same retrieve session only when their `auth_token`s match.

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Waiting for Data Retrieval to Complete

Use the `gp_wait_parallel_retrieve_cursor()` function to display the status of data retrieval from a parallel retrieve cursor, or to wait for all endpoints to finishing retrieving the data. You invoke this function in the transaction block in which you declared the parallel retrieve cursor.

`gp_wait_parallel_retrieve_cursor()` returns `true` only when all tuples are fully retrieved from all endpoints. In all other cases, the function returns `false` and may additionally throw an error.

The function signatures of `gp_wait_parallel_retrieve_cursor()` follow:

```
gp_wait_parallel_retrieve_cursor( cursorname text
)
gp_wait_parallel_retrieve_cursor( cursorname text, timeout_sec int4
)
```

You must identify the name of the cursor when you invoke this function. The timeout argument is optional:

- The default timeout is `0` seconds: WarehousePG checks the retrieval status of all endpoints and returns the result immediately.
- A timeout value of `-1` seconds instructs WarehousePG to block until all data from all endpoints has been retrieved, or block until an error occurs.
- The function reports the retrieval status after a timeout occurs for any other positive timeout value that you specify.

`gp_wait_parallel_retrieve_cursor()` returns when it encounters one of the following conditions:

- All data has been retrieved from all endpoints.
- A timeout has occurred.
- An error has occurred.

Handling Data Retrieval Errors

An error can occur in a retrieve sesson when:

- You cancel or interrupt the retrieve operation.
- The endpoint is only partially retrieved when the retrieve session quits.

When an error occurs in a specific retrieve session, WarehousePG removes the endpoint from the QE. Other retrieve sessions continue to function as normal.

If you close the transaction before fully retrieving from all endpoints, or if `gp_wait_parallel_retrieve_cursor()` returns an error, WarehousePG terminates all remaining open retrieve sessions.

Closing the Cursor

When you have completed retrieving data from the parallel retrieve cursor, close the cursor and end the transaction:

```
CLOSE prc1;
END;
```

> **Note:** When you close a parallel retrieve cursor, WarehousePG terminates any open retrieve sessions associated with the cursor.

On closing, WarehousePG frees all resources associated with the parallel retrieve cursor and its endpoints.

Listing All Parallel Retrieve Cursors

The pg_cursors view lists all declared cursors that are currently available in the system. You can obtain information about all parallel retrieve cursors by running the following command:

```
SELECT * FROM pg_cursors WHERE is_parallel =
true;
```

Listing Segment-Specific Retrieve Session Information

You can obtain information about all retrieve sessions to a specific QE endpoint by invoking the `gp_get_segment_endpoints()` function or examining the `gp_segment_endpoints` view:

```
SELECT * FROM gp_get_segment_endpoints();
SELECT * FROM
gp_segment_endpoints;
```

These commands provide information about the retrieve sessions associated with a QE endpoint for all active parallel retrieve cursors declared by the current user. When the WarehousePG superuser invokes the command, it returns the retrieve session information for all endpoints on the QE created for all parallel retrieve cursors declared by all users.

You can obtain segment-specific retrieve session information in two ways: from the QD, or via a utility-mode connection to the endpoint:

- QD example:

  ```
  SELECT * from gp_dist_random('gp_segment_endpoints');
  ```

  Display the information filtered to a specific segment:

  ```
  SELECT * from gp_dist_random('gp_segment_endpoints') WHERE gp_segment_id = 0;
  ```

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- Example utilizing a utility-mode connection to the endpoint:

```
$ PGOPTIONS='-c gp_session_role=utility' psql -h sdw3 -U localuser -p 6001 -d
testdb

testdb=> SELECT * FROM
gp_segment_endpoints;
```

The commands return endpoint and retrieve session information in a table with the following columns:

Column Name	Description
auth_token	The authentication token for a the retrieve session.
databaseid	The identifier of the database in which the parallel retrieve cursor was created.
senderpid	The identifier of the process sending the query results.
receiverpid	The process identifier of the retrieve session that is receiving the query results.
state	The state of the endpoint; the valid states are: READY: The endpoint is ready to be retrieved. ATTACHED: The endpoint is attached to a retrieve connection. RETRIEVING: A retrieve session is retrieving data from the endpoint at this moment. FINISHED: The endpoint has been fully retrieved. RELEASED: Due to an error, the endpoint has been released and the connection closed.
gp_segment_id	The QE's endpoint `gp_segment_id`.
sessionid	The identifier of the session in which the parallel retrieve cursor was created.
username	The name of the user that initiated the retrieve session.
endpointname	The endpoint identifier.
cursorname	The name of the parallel retrieve cursor.

Refer to the gp_segment_endpoints view reference page for more information about the endpoint attributes returned by these commands.

Limiting the Number of Concurrently Open Cursors

By default, WarehousePG does not limit the number of parallel retrieve cursors that are active in the cluster (up to the maximum value of 1024). The WarehousePG superuser can set thegp_max_parallel_cursors server configuration parameter to limit the number of open cursors.

Known Issues and Limitations

The parallel retrieve cursor implementation has the following limitations:

- The WarehousePG query optimizer (GPORCA) does not support queries on a parallel retrieve cursor.
- WarehousePG ignores the `BINARY` clause when you declare a parallel retrieve cursor.
- Parallel retrieve cursors cannot be declared `WITH HOLD`.
- Parallel retrieve cursors do not support the `FETCH` and `MOVE` cursor operations.
- Parallel retrieve cursors are not supported in SPI; you cannot declare a parallel retrieve cursor in a PL/pgSQL function.

Additional Documentation

Refer to the README in the WarehousePG `github` repository for additional information about the parallel retrieve cursor implementation. You can also find parallel retrieve cursorprogramming examples in the repository.

Example

Create a parallel retrieve cursor and use it to pull query results from a WarehousePG cluster:

1. Open a `psql` session to the WarehousePG coordinator host:

```
psql -d testdb
```

2. Start the transaction:

```
BEGIN;
```

3. Declare a parallel retrieve cursor named `prc1` for a `SELECT *` query on a table:

```
DECLARE prc1 PARALLEL RETRIEVE CURSOR FOR SELECT * FROM
t1;
```

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4. Obtain the endpoints for this parallel retrieve cursor:

```
SELECT * FROM gp_endpoints WHERE cursorname='prc1';
 gp_segment_id |            auth_token             | cursorname | sessionid | hostname | port | username | state |     endpointname
---------------+-----------------------------------+------------+-----------+----------+------+----------+-------+----------------------
             2 | 39a2dc90a82fca668e04d04e0338f105 | prc1       |        51 | sdw1     | 6000 | bill     | READY |
prc10000003300000003
             3 | 1a6b29f0f4cad514a8c3936f9239c50d | prc1       |        51 | sdw1     | 6001 | bill     | READY |
prc10000003300000003
             4 | 1ae948c8650ebd76bfa1a1a9fa535d93 | prc1       |        51 | sdw2     | 6000 | bill     | READY |
prc10000003300000003
             5 | f10f180133acff608275d87966f8c7d9 | prc1       |        51 | sdw2     | 6001 | bill     | READY |
prc10000003300000003
             6 | dda0b194f74a89ed87b592b27ddc0e39 | prc1       |        51 | sdw3     | 6000 | bill     | READY |
prc10000003300000003
             7 | 037f8c747a5dc1b75fb10524b676b9e8 | prc1       |        51 | sdw3     | 6001 | bill     | READY |
prc10000003300000003
             8 | c43ac67030dbc819da9d2fd8b576410c | prc1       |        51 | sdw4     | 6000 | bill     | READY |
prc10000003300000003
             9 | e514ee276f6b2863142aa2652cbccd85 | prc1       |        51 | sdw4     | 6001 | bill     | READY |
prc10000003300000003
(8 rows)
```

5. Wait until all endpoints are fully retrieved:

```
SELECT gp_wait_parallel_retrieve_cursor( 'prc1', -1 );
```

6. For each endpoint:

    1. Open a retrieve session. For example, to open a retrieve session to the segment instance running on `sdw3`, port number `6001`, run the following command in a *different terminal window*; when prompted for the password, provide the `auth_token` identified in row 7 of the `gp_endpoints` output:

    ```
    $ PGOPTIONS='-c gp_retrieve_conn=true' psql -h sdw3 -U localuser -p 6001 -d
    testdb
    Password:
    ```

    2. Retrieve data from the endpoint:

    ```
    -- Retrieve 7 rows of data from this
    session
    RETRIEVE 7 FROM ENDPOINT
    prc10000003300000003
    -- Retrieve the remaining rows of data from this
    session
    RETRIEVE ALL FROM ENDPOINT
    prc10000003300000003
    ```

    3. Exit the retrieve session:

    ```
    \q
    ```

7. In the original `psql` session (the session in which you declared the parallel retrieve cursor), verify that the `gp_wait_parallel_retrieve_cursor()` function returned `t`. Then close the cursor and complete the transaction:

```
CLOSE prc1;
END;
```

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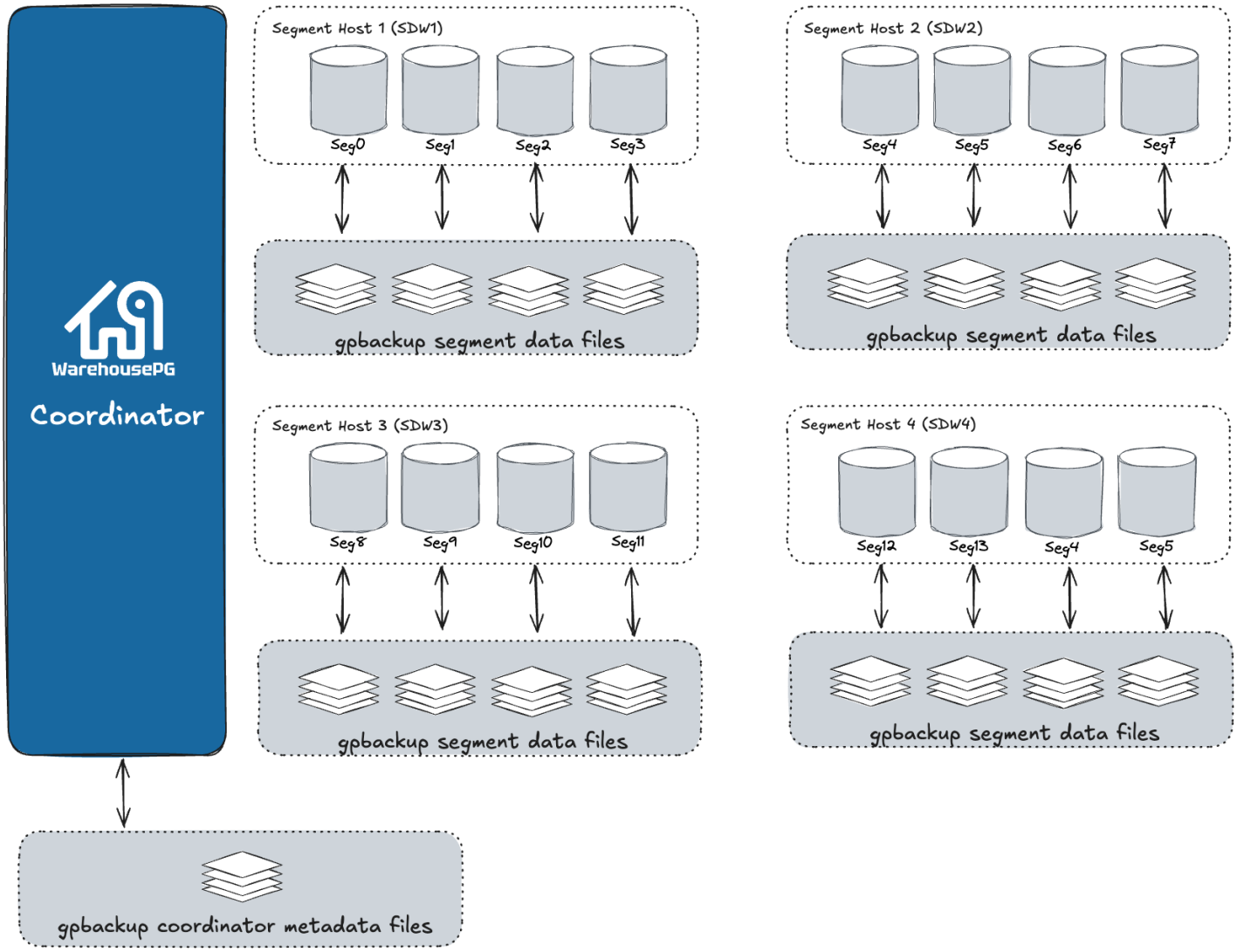
4.12 Backing up WarehousePG with gpbackup and gprestore

Associated Topics

- Incremental backups
- gpbackup syntax reference
- gprestore syntax reference

gpbackup and gprestore are WarehousePG utilities that create and restore backup sets in parallel for WarehousePG. By default, `gpbackup` stores only the object metadata files and DDL files for a backup in the WarehousePG Coordinator data directory. WarehousePG segments use the `COPY ... ON SEGMENT` command to store their data for backed-up tables in compressed CSV data files, located in each segment's backups directory.

Parallel Backup with gpbackup and gprestore



The backup metadata files contain all of the information that `gprestore` needs to restore a full backup set in parallel. Backup metadata also provides the framework for restoring only individual objects in the data set, along with any dependent objects, in future versions of `gprestore`. (See Understanding Backup Files for more information.) Storing the table data in CSV files also provides opportunities for using other restore utilities, such as gpload, to load the data either in the same cluster or another cluster. By default, one file is created for each table on the segment. You can specify the `--leaf-partition-data` option with `gpbackup` to create one data file per leaf partition of a partitioned table, instead of a single file. This option also enables you to filter backup sets by leaf partitions.

Each `gpbackup` task uses a single transaction in WarehousePG. During this transaction, metadata is backed up on the Coordinator host, and data for each table on each segment host is written to CSV backup files using COPY ... ON SEGMENT commands in parallel. The backup process acquires an ACCESS SHARE lock on each table that is backed up.

For additional documenation, visit thegpbackup and gprestore cluster utilities reference page.

- Objects in a backup set
- Backup and Restore Workflow
- Backup History Database
- Using the --include and --exclude filters
- Setting Up Email Alerts
- Backup files layout

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- Return Codes
- Supported WHPG versions
- Limitations

Objects in a backup set

Objects Included in a Backup or Restore The following table lists the objects that are backed up and restored with `gpbackup` and `gprestore`.

Database objects are backed up for the database you specify with the `--dbname` option.

Global objects (WarehousePG Cluster objects) are also backed up by default, but they are restored only if you include the `--with-globals option` when calling `gprestore`. Conversely, the `gpbackup --without-globals` will skip the backup of global objects

Objects that are backed up and restored

Database objects	
Aggregates	Readable External Tables [1]
Casts	Rules
Comments	Schemas [4]
Conversions	Sequences
Domains	Session-level configuration parameter settings (GUCs)
Extensions	Table statistics [2]
Functions	Tables
Indexes	Text search parsers, dictionaries, templates, and configurations
Materialized Views [1]	Triggers [3]
Operators, operator families, and operator classes	Types
Owners	Views
Procedural language extensions	Writable External Tables [1]
Protocols	

1. DDL Only
2. when `--with-stats` flag is used
3. While WarehousePG does not support triggers, trigger definitions present in the database are backed up and restored
4. The following schemas are not part of the backup set: gp_toolkit, information_schema, pg_aoseg, pg_bitmapindex, pg_catalog, pg_toast*, pg_temp*

Global objects	_
Databases	Resource queue definitions
Database-wide configuration parameter settings (GUCs)	Roles
GRANT assignments of roles to databases	Tablespaces
Resource group definitions	

When restoring to an existing database, `gprestore` assumes the public schema exists when restoring objects to the public schema. When restoring to a new database (with the --create-db option), `gprestore` creates the public schema automatically when creating a database with the CREATE DATABASE command. The command uses the template0 database that contains the public schema.

Backup and Restore Workflow

Full Backup

This command will take a full backup (metadata and user data) using zstandard compression

```
$ gpbackup --dbname <database_name> --compression-type zstd
```

Example:

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```
[gpadmin@whpg_cdw ~]$ gpbackup --dbname ww_sales --compression-type zstd
20250514:20:27:13 gpbackup:gpadmin:whpg_cdw:027069-[INFO]:-gpbackup version = 1.30.5
20250514:20:27:13 gpbackup:gpadmin:whpg_cdw:027069-[INFO]:-Greenplum Database Version = 6.27.1 build commit:ab5a612bfdc355ad2d601860dfb70a47778c8dd7
20250514:20:27:13 gpbackup:gpadmin:whpg_cdw:027069-[INFO]:-Starting backup of database ww_sales
20250514:20:27:14 gpbackup:gpadmin:whpg_cdw:027069-[INFO]:-Backup Timestamp = 20250514202713
20250514:20:27:14 gpbackup:gpadmin:whpg_cdw:027069-[INFO]:-Backup Database = ww_sales
20250514:20:27:14 gpbackup:gpadmin:whpg_cdw:027069-[INFO]:-Gathering table state information
20250514:20:27:14 gpbackup:gpadmin:whpg_cdw:027069-[INFO]:-Acquiring ACCESS SHARE locks on tables
Locks acquired:  57 / 57 [============================================================] 100.00% 0s
20250514:20:27:14 gpbackup:gpadmin:whpg_cdw:027069-[INFO]:-Gathering additional table metadata
20250514:20:27:14 gpbackup:gpadmin:whpg_cdw:027069-[INFO]:-Getting partition definitions
20250514:20:27:14 gpbackup:gpadmin:whpg_cdw:027069-[INFO]:-Getting storage information
20250514:20:27:14 gpbackup:gpadmin:whpg_cdw:027069-[INFO]:-Getting child partitions with altered schema
20250514:20:27:14 gpbackup:gpadmin:whpg_cdw:027069-[INFO]:-Metadata will be written to /data/coordinator/gpseg-
1/backups/20250514/20250514202713/gpbackup_20250514202713_metadata.sql
20250514:20:27:14 gpbackup:gpadmin:whpg_cdw:027069-[INFO]:-Writing global database metadata
20250514:20:27:14 gpbackup:gpadmin:whpg_cdw:027069-[INFO]:-Global database metadata backup complete
20250514:20:27:14 gpbackup:gpadmin:whpg_cdw:027069-[INFO]:-Writing pre-data metadata
20250514:20:27:14 gpbackup:gpadmin:whpg_cdw:027069-[INFO]:-Pre-data metadata metadata backup complete
20250514:20:27:14 gpbackup:gpadmin:whpg_cdw:027069-[INFO]:-Writing post-data metadata
20250514:20:27:14 gpbackup:gpadmin:whpg_cdw:027069-[INFO]:-Post-data metadata backup complete
20250514:20:27:14 gpbackup:gpadmin:whpg_cdw:027069-[INFO]:-Writing data to file
Tables backed up:  33 / 33 [============================================================] 100.00% 7s
20250514:20:27:22 gpbackup:gpadmin:whpg_cdw:027069-[INFO]:-Data backup complete
20250514:20:27:22 gpbackup:gpadmin:whpg_cdw:027069-[INFO]:-Skipped data backup of 24 external/foreign table(s).
20250514:20:27:22 gpbackup:gpadmin:whpg_cdw:027069-[INFO]:-See /home/gpadmin/gpAdminLogs/gpbackup_20250514.log for a complete list of skipped tables.
20250514:20:27:23 gpbackup:gpadmin:whpg_cdw:027069-[INFO]:-/home/gpadmin/gp_email_contacts.yaml list found, /data/coordinator/gpseg-
1/backups/20250514/20250514202713/gpbackup_20250514202713_report will be sent
20250514:20:28:23 gpbackup:gpadmin:whpg_cdw:027069-[INFO]:-Beginning cleanup
20250514:20:28:23 gpbackup:gpadmin:whpg_cdw:027069-[INFO]:-Cleanup complete
20250514:20:28:23 gpbackup:gpadmin:whpg_cdw:027069-[INFO]:-Backup completed successfully
```

The above command creates a file that contains global and database-specific metadata on the WarehousePG Coordinator host in the default directory, `$COORDINATOR_DATA_DIRECTORY/backups/<YYYYMMDD>/<YYYYMMDDHHMMSS>/`.

For example:

```
[gpadmin@whpg_cdw 20250514202713]$ ls -ltr /data/coordinator/gpseg-1/backups/20250514/20250514202713
total 2112
-r--r--r-- 1 gpadmin gpadmin 2114041 May 14 20:27 gpbackup_20250514202713_metadata.sql
-r--r--r-- 1 gpadmin gpadmin   35787 May 14 20:27 gpbackup_20250514202713_toc.yaml
-r--r--r-- 1 gpadmin gpadmin    1437 May 14 20:27 gpbackup_20250514202713_config.yaml
-r--r--r-- 1 gpadmin gpadmin    1833 May 14 20:27 gpbackup_20250514202713_report
```

By default, each segment stores each table's data for the backup in a separate compressed CSV file in `<seg_dir>/backups/<YYYYMMDD>/<YYYYMMDDHHMMSS>/`:

```
[gpadmin@mdw 20250514202713]$ ls -ltr /data/primary/gpseg0/backups/20250514/20250514202713
total 125764
-rw------- 1 gpadmin gpadmin      494 May 14 20:27 gpbackup_0_20250514202713_65582.zst
-rw------- 1 gpadmin gpadmin   174123 May 14 20:27 gpbackup_0_20250514202713_67854.zst
-rw------- 1 gpadmin gpadmin  3057086 May 14 20:27 gpbackup_0_20250514202713_67861.zst
-rw------- 1 gpadmin gpadmin 32450223 May 14 20:27 gpbackup_0_20250514202713_70343.zst
-rw------- 1 gpadmin gpadmin  1994875 May 14 20:27 gpbackup_0_20250514202713_71070.zst
-rw------- 1 gpadmin gpadmin   475745 May 14 20:27 gpbackup_0_20250514202713_71077.zst
-rw------- 1 gpadmin gpadmin  3006034 May 14 20:27 gpbackup_0_20250514202713_71084.zst
-rw------- 1 gpadmin gpadmin   528895 May 14 20:27 gpbackup_0_20250514202713_71091.zst
-rw------- 1 gpadmin gpadmin     8945 May 14 20:27 gpbackup_0_20250514202713_71098.zst
-rw------- 1 gpadmin gpadmin       74 May 14 20:27 gpbackup_0_20250514202713_71105.zst
-rw------- 1 gpadmin gpadmin 19507368 May 14 20:27 gpbackup_0_20250514202713_71112.zst
-rw------- 1 gpadmin gpadmin   596995 May 14 20:27 gpbackup_0_20250514202713_71326.zst
-rw------- 1 gpadmin gpadmin     4688 May 14 20:27 gpbackup_0_20250514202713_71333.zst
-rw------- 1 gpadmin gpadmin      251 May 14 20:27 gpbackup_0_20250514202713_71340.zst
-rw------- 1 gpadmin gpadmin      289 May 14 20:27 gpbackup_0_20250514202713_71347.zst
-rw------- 1 gpadmin gpadmin      638 May 14 20:27 gpbackup_0_20250514202713_71354.zst
-rw------- 1 gpadmin gpadmin  4729580 May 14 20:27 gpbackup_0_20250514202713_71361.zst
-rw------- 1 gpadmin gpadmin 44197780 May 14 20:27 gpbackup_0_20250514202713_71575.zst
-rw------- 1 gpadmin gpadmin   198475 May 14 20:27 gpbackup_0_20250514202713_73562.zst
-rw------- 1 gpadmin gpadmin      224 May 14 20:27 gpbackup_0_20250514202713_73569.zst
-rw------- 1 gpadmin gpadmin      634 May 14 20:27 gpbackup_0_20250514202713_73576.zst
-rw------- 1 gpadmin gpadmin  1245122 May 14 20:27 gpbackup_0_20250514202713_73583.zst
-rw------- 1 gpadmin gpadmin 16500913 May 14 20:27 gpbackup_0_20250514202713_73716.zst
-rw------- 1 gpadmin gpadmin     1455 May 14 20:27 gpbackup_0_20250514202713_74227.zst
-rw------- 1 gpadmin gpadmin       13 May 14 20:27 gpbackup_0_20250514202713_74306.zst
-rw------- 1 gpadmin gpadmin       13 May 14 20:27 gpbackup_0_20250514202713_74312.zst
-rw------- 1 gpadmin gpadmin      302 May 14 20:27 gpbackup_0_20250514202713_74318.zst
-rw------- 1 gpadmin gpadmin      278 May 14 20:27 gpbackup_0_20250514202713_74324.zst
-rw------- 1 gpadmin gpadmin      353 May 14 20:27 gpbackup_0_20250514202713_74330.zst
-rw------- 1 gpadmin gpadmin       13 May 14 20:27 gpbackup_0_20250514202713_74336.zst
-rw------- 1 gpadmin gpadmin       13 May 14 20:27 gpbackup_0_20250514202713_74342.zst
-rw------- 1 gpadmin gpadmin       22 May 14 20:27 gpbackup_0_20250514202713_74348.zst
-rw------- 1 gpadmin gpadmin      441 May 14 20:27 gpbackup_0_20250514202713_74351.zst
```

To consolidate all backup files into a single directory, include the `--backup-dir` option with an absolute path to the location you wish to backup to. Optionally, when performing a backup, the `--single-data-file` option may be used in situations where the additional overhead of multiple files might be prohibitive such as third party storage solutions.

The command below shows both options in use

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```
[gpadmin@whpg_cdw ~]$ gpbackup --dbname ww_sales --single-data-file --no-compression --backup-dir /tmp/single_file
20250515:18:22:09 gpbackup:gpadmin:whpg_cdw:032298-[INFO]:-gpbackup version = 1.30.5
20250515:18:22:09 gpbackup:gpadmin:whpg_cdw:032298-[INFO]:-Greenplum Database Version = 6.27.1 build commit:ab5a612bfdc355ad2d601860dfb70a47778c8dd7
20250515:18:22:09 gpbackup:gpadmin:whpg_cdw:032298-[INFO]:-Starting backup of database ww_sales
20250515:18:22:09 gpbackup:gpadmin:whpg_cdw:032298-[INFO]:-Backup Timestamp = 20250515182209
20250515:18:22:09 gpbackup:gpadmin:whpg_cdw:032298-[INFO]:-Backup Database = ww_sales
20250515:18:22:09 gpbackup:gpadmin:whpg_cdw:032298-[INFO]:-Gathering table state information
20250515:18:22:09 gpbackup:gpadmin:whpg_cdw:032298-[INFO]:-Acquiring ACCESS SHARE locks on tables
Locks acquired:  57 / 57 [============================================================] 100.00% 0s
20250515:18:22:09 gpbackup:gpadmin:whpg_cdw:032298-[INFO]:-Gathering additional table metadata
20250515:18:22:09 gpbackup:gpadmin:whpg_cdw:032298-[INFO]:-Getting partition definitions
20250515:18:22:09 gpbackup:gpadmin:whpg_cdw:032298-[INFO]:-Getting storage information
20250515:18:22:09 gpbackup:gpadmin:whpg_cdw:032298-[INFO]:-Getting child partitions with altered schema
20250515:18:22:09 gpbackup:gpadmin:whpg_cdw:032298-[INFO]:-Metadata will be written to /tmp/single_file/gpseg-
1/backups/20250515/20250515182209/gpbackup_20250515182209_metadata.sql
20250515:18:22:09 gpbackup:gpadmin:whpg_cdw:032298-[INFO]:-Writing global database metadata
20250515:18:22:09 gpbackup:gpadmin:whpg_cdw:032298-[INFO]:-Global database metadata backup complete
20250515:18:22:09 gpbackup:gpadmin:whpg_cdw:032298-[INFO]:-Writing pre-data metadata
20250515:18:22:10 gpbackup:gpadmin:whpg_cdw:032298-[INFO]:-Pre-data metadata metadata backup complete
20250515:18:22:10 gpbackup:gpadmin:whpg_cdw:032298-[INFO]:-Writing post-data metadata
20250515:18:22:10 gpbackup:gpadmin:whpg_cdw:032298-[INFO]:-Post-data metadata backup complete
20250515:18:22:10 gpbackup:gpadmin:whpg_cdw:032298-[INFO]:-Writing data to file
Tables backed up:  33 / 33 [============================================================] 100.00% 8s
20250515:18:22:18 gpbackup:gpadmin:whpg_cdw:032298-[INFO]:-Data backup complete
20250515:18:22:18 gpbackup:gpadmin:whpg_cdw:032298-[INFO]:-Skipped data backup of 24 external/foreign table(s).
20250515:18:22:18 gpbackup:gpadmin:whpg_cdw:032298-[INFO]:-See /home/gpadmin/gpAdminLogs/gpbackup_20250515.log for a complete list of skipped tables.
20250515:18:22:19 gpbackup:gpadmin:whpg_cdw:032298-[INFO]:-Found neither /usr/local/greenplum-db-6.27.1/bin/gp_email_contacts.yaml nor
/home/gpadmin/gp_email_contacts.yaml
20250515:18:22:19 gpbackup:gpadmin:whpg_cdw:032298-[INFO]:-Email containing gpbackup report /tmp/single_file/gpseg-
1/backups/20250515/20250515182209/gpbackup_20250515182209_report will not be sent
20250515:18:22:19 gpbackup:gpadmin:whpg_cdw:032298-[INFO]:-Beginning cleanup
20250515:18:22:24 gpbackup:gpadmin:whpg_cdw:032298-[INFO]:-Cleanup complete
20250515:18:22:24 gpbackup:gpadmin:whpg_cdw:032298-[INFO]:-Backup completed successfully
```

The contents of the corresponding backup directories show the single data file, and it's associated table of contents files (toc). Both files are required for a successful restore.

```
[gpadmin@whpg_cdw ~]$ ls -ltr /tmp/single_file/gp*/backups/*/*

/tmp/single_file/gpseg0/backups/20250515/20250515182209:
total 407012
-rw-rw-r-- 1 gpadmin gpadmin 416771752 May 15 18:22 gpbackup_0_20250515182209
-r--r--r-- 1 gpadmin gpadmin      1864 May 15 18:22 gpbackup_0_20250515182209_toc.yaml

/tmp/single_file/gpseg1/backups/20250515/20250515182209:
total 434396
-rw-rw-r-- 1 gpadmin gpadmin 444811433 May 15 18:22 gpbackup_1_20250515182209
-r--r--r-- 1 gpadmin gpadmin      1864 May 15 18:22 gpbackup_1_20250515182209_toc.yaml

/tmp/single_file/gpseg2/backups/20250515/20250515182209:
total 407260
-rw-rw-r-- 1 gpadmin gpadmin 417025293 May 15 18:22 gpbackup_2_20250515182209
-r--r--r-- 1 gpadmin gpadmin      1864 May 15 18:22 gpbackup_2_20250515182209_toc.yaml

/tmp/single_file/gpseg-1/backups/20250515/20250515182209:
total 2112
-r--r--r-- 1 gpadmin gpadmin 2114041 May 15 18:22 gpbackup_20250515182209_metadata.sql
-r--r--r-- 1 gpadmin gpadmin   35787 May 15 18:22 gpbackup_20250515182209_toc.yaml
-r--r--r-- 1 gpadmin gpadmin    1451 May 15 18:22 gpbackup_20250515182209_config.yaml
-r--r--r-- 1 gpadmin gpadmin    1872 May 15 18:22 gpbackup_20250515182209_report
```

Full Restore

To use `gprestore` to restore from a backup set, you must use the `--timestamp` option to specify the exact timestamp value (YYYYMMDDHHMMSS) to restore. Include the `--create-db` option if the database does not exist in the cluster. If you specified a custom --backup-dir to consolidate the backup files, include the same `--backup-dir` option when using `gprestore` to locate the backup files.

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```
[gpadmin@whpg_cdw ~]$ psql -c "DROP DATABASE ww_sales";
DROP DATABASE
[gpadmin@whpg_cdw ~]$
[gpadmin@whpg_cdw ~]$ gprestore --timestamp 20250515182209 --backup-dir /tmp/single_file --create-db
20250515:18:35:09 gprestore:gpadmin:whpg_cdw:032941-[INFO]:-Restore Key = 20250515182209
20250515:18:35:09 gprestore:gpadmin:whpg_cdw:032941-[INFO]:-gpbackup version = 1.30.5
20250515:18:35:09 gprestore:gpadmin:whpg_cdw:032941-[INFO]:-gprestore version = 1.30.5
20250515:18:35:09 gprestore:gpadmin:whpg_cdw:032941-[INFO]:-Greenplum Database Version = 6.27.1 build commit:ab5a612bfdc355ad2d601860dfb70a47778c8dd7
20250515:18:35:09 gprestore:gpadmin:whpg_cdw:032941-[INFO]:-Creating database
20250515:18:35:10 gprestore:gpadmin:whpg_cdw:032941-[INFO]:-Database creation complete for: ww_sales
20250515:18:35:10 gprestore:gpadmin:whpg_cdw:032941-[INFO]:-Restoring pre-data metadata
Pre-data objects restored:  153 / 153 [================================================] 100.00% 3s
20250515:18:35:14 gprestore:gpadmin:whpg_cdw:032941-[INFO]:-Pre-data metadata restore complete
Tables restored:  33 / 33 [============================================================] 100.00% 38s
20250515:18:35:52 gprestore:gpadmin:whpg_cdw:032941-[INFO]:-Data restore complete
20250515:18:35:52 gprestore:gpadmin:whpg_cdw:032941-[INFO]:-Restoring post-data metadata
20250515:18:35:52 gprestore:gpadmin:whpg_cdw:032941-[INFO]:-Post-data metadata restore complete
20250515:18:35:52 gprestore:gpadmin:whpg_cdw:032941-[INFO]:-Found neither /usr/local/greenplum-db-6.27.1/bin/gp_email_contacts.yaml nor
/home/gpadmin/gp_email_contacts.yaml
20250515:18:35:52 gprestore:gpadmin:whpg_cdw:032941-[INFO]:-Email containing gprestore report /tmp/single_file/gpseg-
1/backups/20250515/20250515182209/gprestore_20250515182209_20250515183509_report will not be sent
20250515:18:35:52 gprestore:gpadmin:whpg_cdw:032941-[INFO]:-Beginning cleanup
20250515:18:36:00 gprestore:gpadmin:whpg_cdw:032941-[INFO]:-Cleanup complete
20250515:18:36:00 gprestore:gpadmin:whpg_cdw:032941-[INFO]:-Restore completed successfully
```

`gprestore` does not attempt to restore global metadata for the WarehousePG Cluster by default. If this is required, include the `--with-globals` option.

By default, `gprestore` uses 1 connection to restore table data and metadata. If you have a large backup set which **did not use** the `--single-data-file` option, restore duration can be decreased by specifiying the number of parallel processes using the `--jobs` option. Depending on system resourceds and database size, this number can be tuned for each specific environment.

```
[gpadmin@whpg_cdw ~]$ psql -c "DROP DATABASE ww_sales";
DROP DATABASE
[gpadmin@whpg_cdw ~]$
[gpadmin@whpg_cdw ~]$ gprestore --timestamp 20250514202713 --create-db --jobs 4
20250515:18:40:40 gprestore:gpadmin:whpg_cdw:033527-[INFO]:-Restore Key = 20250514202713
20250515:18:40:40 gprestore:gpadmin:whpg_cdw:033527-[INFO]:-gpbackup version = 1.30.5
20250515:18:40:40 gprestore:gpadmin:whpg_cdw:033527-[INFO]:-gprestore version = 1.30.5
20250515:18:40:40 gprestore:gpadmin:whpg_cdw:033527-[INFO]:-Greenplum Database Version = 6.27.1 build commit:ab5a612bfdc355ad2d601860dfb70a47778c8dd7
20250515:18:40:40 gprestore:gpadmin:whpg_cdw:033527-[INFO]:-Creating database
20250515:18:40:41 gprestore:gpadmin:whpg_cdw:033527-[INFO]:-Database creation complete for: ww_sales
20250515:18:40:41 gprestore:gpadmin:whpg_cdw:033527-[INFO]:-Restoring pre-data metadata
Pre-data objects restored:  153 / 153 [================================================] 100.00% 2s
20250515:18:40:43 gprestore:gpadmin:whpg_cdw:033527-[INFO]:-Pre-data metadata restore complete
Tables restored:  33 / 33 [============================================================] 100.00% 16s
20250515:18:41:00 gprestore:gpadmin:whpg_cdw:033527-[INFO]:-Data restore complete
20250515:18:41:00 gprestore:gpadmin:whpg_cdw:033527-[INFO]:-Restoring post-data metadata
20250515:18:41:00 gprestore:gpadmin:whpg_cdw:033527-[INFO]:-Post-data metadata restore complete
20250515:18:41:00 gprestore:gpadmin:whpg_cdw:033527-[INFO]:-Found neither /usr/local/greenplum-db-6.27.1/bin/gp_email_contacts.yaml nor
/home/gpadmin/gp_email_contacts.yaml
20250515:18:41:00 gprestore:gpadmin:whpg_cdw:033527-[INFO]:-Email containing gprestore report /data/coordinator/gpseg-
1/backups/20250514/20250514202713/gprestore_20250514202713_20250515184040_report will not be sent
20250515:18:41:00 gprestore:gpadmin:whpg_cdw:033527-[INFO]:-Beginning cleanup
20250515:18:41:00 gprestore:gpadmin:whpg_cdw:033527-[INFO]:-Cleanup complete
20250515:18:41:00 gprestore:gpadmin:whpg_cdw:033527-[INFO]:-Restore completed successfully
[gpadmin@whpg_cdw ~]$
```

Report Files

When performing a backup or restore operation, `gpbackup` and `gprestore` generate a report file. When email notification is configured, the email sent contains the contents of the report file. For information about email notification, see Configuring Email Notifications.

The report file is placed in the WarehousePG Coordinator backup directory. The report file name contains the timestamp of the operation. These are the formats of the `gpbackup` and `gprestore` report file names.

- `gpbackup_<backup_timestamp>_report`
- `gprestore_<backup_timestamp>_<restore_timesamp>_report`

For these example report file names, `20250518010000` is the timestamp of the backup and `20250530234643` is the timestamp of the restore operation.

`gpbackup_20250518010000_report`

`gprestore_20250518010000_20180213115426_report`

This backup directory on a WarehousePG Coordinator host contains both a `gpbackup` and `gprestore` report file.

```
[gpadmin@cdw 20250530234643]$ ls -ltr
total 2124
-r--r--r-- 1 gpadmin gpadmin 2120143 May 30 23:46 gpbackup_20250530234643_metadata.sql
-r--r--r-- 1 gpadmin gpadmin   38064 May 30 23:46 gpbackup_20250530234643_toc.yaml
-r--r--r-- 1 gpadmin gpadmin    1499 May 30 23:46 gpbackup_20250530234643_config.yaml
-r--r--r-- 1 gpadmin gpadmin    1837 May 30 23:46 gpbackup_20250530234643_report
-r--r--r-- 1 gpadmin gpadmin     539 May 31 00:05 gprestore_20250530234643_20250531000515_report
```

The contents of the report files are similar. This is an example of the contents of a `gprestore` report file.

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```
WarehousePG Report

timestamp key:           20250530234643
gpdb version:            6.27.1 build commit:ab5a612bfdc355ad2d601860dfb70a47778c8dd7
gprestore version:       1.30.5

database name:           test
command line:            gprestore --timestamp 20250530234643 --redirect-db test --create-db

backup segment count:    8
restore segment count:   8
start time:              Sat May 31 2025 00:05:15
end time:                Sat May 31 2025 00:05:57
duration:                0:00:42

restore status:          Success
```

Backup History Database

`gpbackup` stores details of each backup operation in a SQLite database found in `$COORDINATOR_DATA_DIRECTORY/gpbackup_history.db`. Details such as timestamps, command line options, incremental backup details and status are stored in this database. `gpbackup_history.db` is not backed up my `gpbackup`, but can be copied to a secondary location if a backup copy is desired.

`gpbackup` uses the metadata in `gpbackup_history.db` to create the backup/restore plan for an incremental backup sets when you run `gpbackup` with the `--incremental` option and do not specify the `--from-timesamp` option to indicate the backup that you want to use as the base backup of the incremental backup set. For information about incremental backups, refer toIncremental Backups with `gpbackup` and `gprestore`.

Filtering the Contents of a Backup or Restore

`gpbackup` backs up all schemas and tables in the specified database, unless you exclude or include individual schema or table objects with schema level or table level filter options.

The schema level options are

- `--include-schema`
- `--include-schema-file`
- `--exclude-schema`
- `--exclude-schema-file`

command-line options to `gpbackup`. For example, if the `ww_customer` database contains three schemas, `na_customer`, `apac_customer`, `emea_customer`, the following commands back up only the `apac_customer` and `emea_customer` schemas:

```
$ gpbackup --dbname ww_customer --exclude-schema na_customer
```

Multiple `--include-schema` options may be used in a `gpbackup` or multiple `--exclude-schema` options to filter 2 or many schemas

```
$ gpbackup --dbname ww_customer --include-schema apac_customer --include-schema emea_customer
```

An alternative to multiple command line options is to use `--include-schema-file` or `--exclude-schema-file`. Each line in the file defines a single schema, and the file cannot contain trailing lines.

`/tmp/nw_states.schema` contents

```
[gpadmin@whpg_cdw tmp]$ cat nw_states.schema
Washington
Oregon
Idaho
Montana
Wyoming
[gpadmin@whpg_cdw tmp]$
```

Example of the command:

```
gpbackup --dbname ww_customer --include-schema-file /tmp/nw_states.schema
```

Filtering included or excluded tables is similar process to schemas.

- `--include-table`
- `--exclude-table`
- `--include-table-file`
- `--exclude-table-file`

Options use the `schema-name.table-name` format as input on the command line, and in the text file. The individual table filtering options can be used multiple times, but `--include-table` and `--exclude-table` cannot both be used in the same command.

You can create a list of qualified table names in a text file. Each line in the file defines a single `schema-name.table-name`, and the file cannot contain trailing lines.

```
gpbackup --dbname ww_customer --include-table apac_customer.customer_fact
```

or

```
gpbackup --dbname ww_customer --exclude-table-file /tmp/exclude_tables.file
```

where `/tmp/include_tables.file` contents

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```
[gpadmin@whpg_cdw tmp]$ cat exclude_tables.file
emea_customer.customer_fact
na_customer.customer_fact
[gpadmin@whpg_cdw tmp]$
```

Table and schema names containing upper case letters or spaces must be enclosed with double quotes.

```
[gpadmin@whpg_cdw tmp]$ cat exclude_tables_2.file
emea_customer.customer_fact
na_customer.customer_fact
na_customer."ZipCodes"
"WW_GEO".holidays
"WW_GEO"."time zones"
[gpadmin@whpg_cdw tmp]$
```

When `--include-table` or `--include-table-file` is specified on the command line, dependent objects are not automatically backed up or restored. Depenedent objects must be specified in your filter string or file. For example, if you back up or restore a view or materialized view, you must also list the table(s) the view or the materialized view require. If you backup or restore a table containing a sequence, you must also specify the sequence name.

Filtering by Leaf Partition

By default, `gpbackup` creates one file for each table on a data segment. When the `--leaf-partition-data` option is used, `gpbackup` will create one data file per leaf partition of a partitioned table, instead of a single file data file for the root table. You can also filter backups to specific leaf partitions by including the names of the leaf partitions names as you would a stand along table, using the `schema_name.table_name` format.

```
gpadmin=# \d+ ww_inventory
                                Table "WW_GEO.ww_inventory"
        Column         |       Type        | Modifiers | Storage  | Stats target | Description
-----------------------+-------------------+-----------+----------+--------------+-------------
 prod_id               | integer           |           | plain    |              |
 prod_sku              | character varying |           | extended |              |
 prod_warehouse        | character varying |           | extended |              |
 prod_qty_on_hand      | integer           |           | plain    |              |
 prod_date_inventoried | date              |           | plain    |              |
Child tables: ww_inventory_1_prt_1,
              ww_inventory_1_prt_10,
              ww_inventory_1_prt_11,
              ww_inventory_1_prt_12,
              ww_inventory_1_prt_13,
              ww_inventory_1_prt_14,
              ww_inventory_1_prt_15,
              ww_inventory_1_prt_16,
              ww_inventory_1_prt_17,
              ww_inventory_1_prt_18,
              ww_inventory_1_prt_19,
              ww_inventory_1_prt_2,
              ww_inventory_1_prt_20,
              ww_inventory_1_prt_21,
              ww_inventory_1_prt_22,
              ww_inventory_1_prt_23,
              ww_inventory_1_prt_24,
              ww_inventory_1_prt_25,
              ww_inventory_1_prt_26,
              ww_inventory_1_prt_27,
              ww_inventory_1_prt_28,
              ww_inventory_1_prt_29,
              ww_inventory_1_prt_3,
              ww_inventory_1_prt_30,
              ww_inventory_1_prt_4,
              ww_inventory_1_prt_5,
              ww_inventory_1_prt_6,
              ww_inventory_1_prt_7,
              ww_inventory_1_prt_8,
              ww_inventory_1_prt_9
Distributed by: (prod_id)
Partition by: (prod_date_inventoried)
```

The following file `/tmp/may_week1.include` contains the partitions for the first week of May which will be included in our `gpbackup`

```
[gpadmin@whpg_cdw ~]$ cat /tmp/may_week1.include
"WW_GEO".ww_inventory_1_prt_1
"WW_GEO".ww_inventory_1_prt_2
"WW_GEO".ww_inventory_1_prt_3
"WW_GEO".ww_inventory_1_prt_4
"WW_GEO".ww_inventory_1_prt_5
"WW_GEO".ww_inventory_1_prt_6
"WW_GEO".ww_inventory_1_prt_7
```

Using the `--include-table-file` and `--leaf-partition-data` options, `gpbackup` will create one data file for each leaf partition specified in the input file

```
$ gpbackup --dbname ww_sales --include-table-file /tmp/may_week1.include --leaf-partition-data
```

The `--exclude-table-file` option and `--leaf-partition-data` are not compatible. Although you can specify leaf partition names in a file specified with `--exclude-table-file`, `gpbackup` ignores the partition names.

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Filtering with `gprestore`

After creating a backup set with `gpbackup`, you can filter the schemas and tables that you want to restore from the backup set using the `gprestore --include-schema` and `--include-table-file` options. These options work in the same way as their `gpbackup` counterparts, but have the following restrictions:

The tables that you attempt to restore must not already exist in the database.

If you attempt to restore a schema or table that does not exist in the backup set, the `gprestore` does not run.

If you use the `--include-schema` option, `gprestore` cannot restore objects that have dependencies on multiple schemas.

If you use the `--include-table-file` option, `gprestore` does not create roles or set the owner of the tables. The utility restores table indexes and rules. Triggers are also restored but are not supported in WarehousePG.

The file that you specify with `--include-table-file` cannot include a leaf partition name, as it can when you specify this option with `gpbackup`. If you specified leaf partitions in the backup set, specify the partitioned table to restore the leaf partition data.

When restoring a backup set that contains data from some leaf partitions of a partitioned table, the partitioned table is restored along with the data for the leaf partitions. For example, you create a backup with the `gpbackup` option `--include-table-file` and the text file lists some leaf partitions of a partitioned table. Restoring the backup creates the partitioned table and restores the data only for the leaf partitions listed in the file.

Setting Up Email Alerts

`gpbackup` and `gprestore` can send email notifications via `sendmail` after a backup or restore run completes.

To have `gpbackup` or `gprestore` send out status email notifications, a `gp_email_contacts.yaml` file must exist in either home directory of the user running `gpbackup` or `gprestore` or the same directory as the utilities ($GPHOME/bin).

If the `gp_email_contacts.yaml` file is not present, the gpbackup/gprestore log file will have a message similar to:

```
20250530:23:46:52 gpbackup:gpadmin:cdw:022290-[INFO]:-Data backup complete
20250530:23:46:52 gpbackup:gpadmin:cdw:022290-[INFO]:-Skipped data backup of 24 external/foreign table(s).
20250530:23:46:52 gpbackup:gpadmin:cdw:022290-[INFO]:-See /home/gpadmin/gpAdminLogs/gpbackup_20250530.log for a complete list of skipped tables.
20250530:23:46:53 gpbackup:gpadmin:cdw:022290-[INFO]:-Found neither /usr/local/greenplum-db-6.27.1/bin/gp_email_contacts.yaml nor
/home/gpadmin/gp_email_contacts.yaml
20250530:23:46:53 gpbackup:gpadmin:cdw:022290-[INFO]:-Email containing gpbackup report /data/coordinator/gpseg-
1/backups/20250530/20250530234643/gpbackup_20250530234643_report will not be sent
20250530:23:46:53 gpbackup:gpadmin:cdw:022290-[INFO]:-Beginning cleanup
20250530:23:46:53 gpbackup:gpadmin:cdw:022290-[INFO]:-Cleanup complete
20250530:23:46:53 gpbackup:gpadmin:cdw:022290-[INFO]:-Backup completed successfully
```

If the `gp_email_contacts.yaml` file is present, can configured properly, a similar message will be printed to the logs:

```
20250514:20:27:23 gpbackup:gpadmin:whpg_cdw:027069-[INFO]:-/home/gpadmin/gp_email_contacts.yaml list found, /data/coordinator/gpseg-
1/backups/20250514/20250514202713/gpbackup_20250514202713_report will be sent```
```

The `$HOME/gp_email_contacts.yaml` file will override any configurations found in the `$GPHOME/bin/gp_email_contacts.yaml`

The email subject line includes the utility name, timestamp, status, and the name of the WarehousePG Coordinator. This is an example subject line for a `gpbackup` email.

```
gpbackup 20250514202713 on whpg_cdw completed: Success
```

or

```
gprestore 20250515182209 on whpg_cdw completed: Failure
```

The email contains summary information about the operation including options, duration, and number of objects backed up or restored. For information about the contents of a notification email, see Report Files.

gp_email_contacts.yaml file format

The `gpbackup` and `gprestore` email notification YAML file gp_email_contacts.yaml uses indentation (spaces) to determine the document hierarchy and the relationships of the sections to one another. The use of white space is significant. White space should not be used simply for formatting purposes, and tabs should not be used at all.

Note: If the status parameters are not specified correctly, the utility does not issue a warning. For example, if the success parameter is misspelled and is set to true, a warning is not issued and an email is not sent to the email address after a successful operation. To ensure email notification is configured correctly, run tests with email notifications configured.

This is the format of the gp_email_contacts.yaml YAML file for `gpbackup` email notifications:

```
contacts:
  gpbackup:
  - address: name@domain
    status:
         success: [true | false]
         success_with_errors: [true | false]
         failure: [true | false]
  gprestore:
  - address: name@domain
    status:
         success: [true | false]
         success_with_errors: [true | false]
         failure: [true | false]
```

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Email YAML File Sections

contacts: Required. The section that contains the `gpbackup` and `gprestore` sections. The YAML file can contain a `gpbackup` section, a `gprestore` section, or one of each.

gpbackup : Optional. Begins the gpbackup email section.

address : Required. At least one email address must be specified. Multiple email address parameters can be specified. Each address requires a status section.

> **Note**
>
> name@domainis a single, valid email address.

status : Required. Specify when the utility sends an email to the specified email address. The default is to not send email notification.

You specify sending email notifications based on the completion status of a backup or restore operation. At least one of these parameters must be specified and each parameter can appear at most once.

success : Optional. Specify if an email is sent if the operation completes without errors. If the value is true, an email is sent if the operation completes without errors. If the value is false (the default), an email is not sent.

success_with_errors : Optional. Specify if an email is sent if the operation completes with errors. If the value is true, an email is sent if the operation completes with errors. If the value is false (the default), an email is not sent.

failure : Optional. Specify if an email is sent if the operation fails. If the value is true, an email is sent if the operation fails. If the value is false (the default), an email is not sent.

gprestore : Optional. Begins the gprestore email section. This section contains the address and status parameters that are used to send an email notification after a `gprestore` operation. The syntax is the same as the gpbackup section.

Examples

This example YAML file specifies sending email to email addresses depending on the success or failure of an operation. For a backup operation, an email is sent to a different address depending on the success or failure of the backup operation. For a restore operation, an email is sent to single address only when the operation succeeds or completes with errors.

```
contacts:
  gpbackup:
  - address: dba_backup_success@whpg.io
    status:
      success:true
  - address: dba_backup_failure@whpg.io
    status:
      success_with_errors: true
      failure: true
  gprestore:
  - address: dba_restore_status@example.com
    status:
      success: true
      success_with_errors: true
```

Backup Files Details

A complete backup set for `gpbackup` includes multiple metadata files, supporting files, and CSV data files, each designated with the timestamp at which the backup was created.

By default, metadata and supporting files are stored on the WarehousePG coordinator host in the directory `$COORDINATOR_DATA_DIRECTORY/backups/YYYYMMDD/YYYYMMDDHHMMSS/` . If you specify a custom backup directory, this same file path is created as a subdirectory of the backup directory. The following table describes the names and contents of the metadata and supporting files.

> **Warning:**
>
> All `gpbackup` metadata files are created with read-only permissions. Never delete or modify the metadata files for a `gpbackup` backup set. Doing so may render the backup files non-functional.

Coordinator Metadata Files

`gpbackup_<YYYYMMDDHHMMSS>_metadata.sql`

Contains global and database-specific metadata:

- DDL for objects that are global to the WarehousePG cluster, and not owned by a specific database within the cluster.
- DDL for objects in the backed-up database (specified with --dbname) that must be created before to restoring the actual data, and DDL for objects that must be created after restoring the data.

Global objects include:

- Tablespaces
- Databases
- Database-wide configuration parameter settings (GUCs)
- Resource group definitions
- Resource queue definitions
- Roles
- GRANT assignments of roles to databases

> **Note**
>
> Note: Global metadata is not restored by default. You must include the --with-globals option to the `gprestore` command to restore global metadata.

Database-specific objects that must be created before to restoring the actual data include:

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- Session-level configuration parameter settings (GUCs)
- Schemas
- Procedural language extensions
- Types
- Sequences
- Functions
- Tables
- Protocols
- Operators and operator classes
- Conversions
- Aggregates
- Casts
- Views
- Materialized Views (only view definition is backed up / restored, not data)
- Constraints
- Database-specific objects that must be created after restoring the actual data include:
- Indexes
- Rules
- Triggers. (While WarehousePG does not support triggers, any trigger definitions that are present are backed up and restored.)

example:

```
CREATE TABLE uat.refund (
        returned_date_sk integer,
        returned_time_sk integer,
        item_sk integer,
        refunded_customer_sk integer,
        refunded_cdemo_sk integer,
        refunded_hdemo_sk integer,
) DISTRIBUTED RANDOMLY;

ALTER TABLE uat.refund OWNER TO gpadmin;

CREATE INDEX item_sk_cr_fee_idx ON uat.refund USING btree (item_sk, fee);

CREATE INDEX item_sk_idx ON uat.refund USING btree (item_sk);
```

`gpbackup_<YYYYMMDDHHMMSS>_toc.yaml`

Table of contents file, containing location information of the various object DDL in the `gpbackup_<YYYYMMDDHHMMSS>_metadata.sql` files

This file also contains the table names and OIDs used for locating the corresponding table data in CSV data files that are created on each segment.

example:

```
- schema: tpcds
  name: household_demographics
  oid: 37231
  attributestring: (hd_demo_sk,hd_income_band_sk,hd_buy_potential,hd_dep_count,hd_vehicle_count)
  rowscopied: 7200
  partitionroot: ""
  isreplicated: false
  distbyenum: false
- schema: tpcds
  name: income_band
  oid: 37238
  attributestring: (ib_income_band_sk,ib_lower_bound,ib_upper_bound)
  rowscopied: 20
  partitionroot: ""
  isreplicated: false
  distbyenum: false
- schema: tpcds
  name: inventory
  oid: 37245
  attributestring: (inv_date_sk,inv_item_sk,inv_warehouse_sk,inv_quantity_on_hand)
  rowscopied: 11745000
  partitionroot: ""
  isreplicated: false
  distbyenum: false
```

See Segment Data Files

`gpbackup_<YYYYMMDDHHMMSS>_report`

Contains information about the backup operation that is used to populate the email notice (if configured) that is sent after the backup completes. This file contains information such as:

- Command-line options that were provided
- Database that was backed up
- Database version
- Backup type

example:

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```
WarehousePG Backup Report

timestamp key:         20250530232002
gpdb version:          6.27.1 build commit:ab5a612bfdc355ad2d601860dfb70a47778c8dd7
gpbackup version:      1.30.5

database name:         whpg_tpcds
command line:          gpbackup --dbname whpg_tpcds --no-compression --single-data-file --backup-dir /tmp/whpg_tpcds_backups
compression:           None
plugin executable:     None
backup section:        All Sections
object filtering:      None
includes statistics:   No
data file format:      Single Data File Per Segment
incremental:           False

start time:            Fri May 30 2025 23:20:02
end time:              Fri May 30 2025 23:20:13
duration:              0:00:11

backup status:         Success

database size:         1699 MB
segment count:         3

count of database objects in backup:
aggregates                   0
casts                        0
collations                   0
constraints                  0
conversions                  0
default privileges           0
database gucs                1
event triggers               0
extensions                   0
foreign data wrappers        0
foreign servers              0
functions                    0
indexes                      2
```

See Setting Up Email Alerts

`gpbackup_<YYYYMMDDHHMMSS>_config.yaml`

Contains metadata about the execution of the particular backup task, including:

- `gpbackup` version
- Database name
- WarehousePG version
- Additional option settings such as `--no-compression`, `--compression-level`, `--metadata-only`, `--data-only`, and `--with-stats`.

example:

```
backupdir: /tmp/whpg_tpcds_backups
backupversion: 1.30.5
compressed: false
compressiontype: gzip
databasename: whpg_tpcds
databaseversion: 6.27.1 build commit:ab5a612bfdc355ad2d601860dfb70a47778c8dd7
segmentcount: 8
dataonly: false
datedeleted: ""
excluderelations: []
excludeschemafiltered: false
excludeschemas: []
excludetablefiltered: false
includerelations: []
includeschemafiltered: false
includeschemas: []
includetablefiltered: false
incremental: false
leafpartitiondata: false
metadataonly: false
plugin: ""
pluginversion: ""
restoreplan:
- timestamp: "20250530232002"
  tablefqns:
  - tpcds.call_center
  - tpcds.catalog_page
  - tpcds.catalog_returns
  - tpcds.catalog_sales
  - tpcds.customer
  - tpcds.customer_address
  - tpcds.customer_demographics
```

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Segment Data Files

By default, each segment creates one compressed CSV file for each table that is backed up on the segment. You can optionally specify the `--single-data-file` option to create a single data file on each segment. The files are stored in `<seg_dir>/backups/YYYYMMDD/YYYYMMDDHHMMSS/`.

If you specify a custom backup directory, segment data files are copied to this same file path as a subdirectory of the backup directory. If you include the `--leaf-partition-data` option, `gpbackup` creates one data file for each leaf partition of a partitioned table, instead of just one table for file.

By default, each table is backed up into a distinct file on the segment hosts: The file uses a name format `gpbackup_<content_id>_<YYYYMMDDHHMMSS>_<oid>.gz` where:

`<content_id>` is the content ID of the segment. `<YYYYMMDDHHMMSS>` is the timestamp of the `gpbackup` operation. `<oid>` is the object ID of the table.

default multiple data file example

```
-rw------- 1 gpadmin gpadmin      216 May 30 23:46 gpbackup_1_20250530234643_32812.zst
-rw------- 1 gpadmin gpadmin   177641 May 30 23:46 gpbackup_1_20250530234643_32822.zst
-rw------- 1 gpadmin gpadmin  3080557 May 30 23:46 gpbackup_1_20250530234643_32829.zst
-rw------- 1 gpadmin gpadmin 32449514 May 30 23:46 gpbackup_1_20250530234643_36476.zst
-rw------- 1 gpadmin gpadmin  1989827 May 30 23:46 gpbackup_1_20250530234643_37203.zst
-rw------- 1 gpadmin gpadmin   475551 May 30 23:46 gpbackup_1_20250530234643_37210.zst
-rw------- 1 gpadmin gpadmin  3002507 May 30 23:46 gpbackup_1_20250530234643_37217.zst
-rw------- 1 gpadmin gpadmin   535332 May 30 23:46 gpbackup_1_20250530234643_37224.zst
-rw------- 1 gpadmin gpadmin     8895 May 30 23:46 gpbackup_1_20250530234643_37231.zst
-rw------- 1 gpadmin gpadmin       74 May 30 23:46 gpbackup_1_20250530234643_37238.zst
-rw------- 1 gpadmin gpadmin 19518846 May 30 23:46 gpbackup_1_20250530234643_37245.zst
-rw------- 1 gpadmin gpadmin   606613 May 30 23:46 gpbackup_1_20250530234643_37459.zst
-rw------- 1 gpadmin gpadmin     4595 May 30 23:46 gpbackup_1_20250530234643_37466.zst
-rw------- 1 gpadmin gpadmin      177 May 30 23:46 gpbackup_1_20250530234643_37473.zst
-rw------- 1 gpadmin gpadmin      152 May 30 23:46 gpbackup_1_20250530234643_37480.zst
-rw------- 1 gpadmin gpadmin      327 May 30 23:46 gpbackup_1_20250530234643_37487.zst
-rw------- 1 gpadmin gpadmin  4710343 May 30 23:46 gpbackup_1_20250530234643_37494.zst
```

`--single-data-file` example

All table data for a particular segment is written to a single file:

- `gpbackup_<content_id>_<YYYYMMDDHHMMSS>`

With a corresponding table of contents files:

- `gpbackup_<content_id>_<YYYYMMDDHHMMSS>_toc.yaml`

```
-rw-rw-r-- 1 gpadmin gpadmin 417025744 May 30 23:20 gpbackup_0_20250530232002
-r--r--r-- 1 gpadmin gpadmin      2035 May 30 23:20 gpbackup_0_20250530232002_toc.yaml
```

The metadata file `gpbackup_<YYYYMMDDHHMMSS>_toc.yaml` references this `<oid>` to locate the data for a specific table in a schema.

You can optionally specify the gzip compression level (from 1-9) using the `--compression-level` option, or disable compression entirely with `--no-compression`. If you do not specify a compression level, `gpbackup` uses compression level 1 by default.

Return Codes

One of these codes is returned after `gpbackup` or `gprestore` completes.

0 – Backup or restore completed with no problems
1 – Backup or restore completed with non-fatal errors. See log file for more information.
2 – Backup or restore failed with a fatal error. See log file for more information.

Supported WHPG versions

The WarehousePG provided `gpbackup` and `gprestore` utilities are compatible with WarehousePG versions

- 6.27.1 or later
- 7.2.1-WHPG or later

Limitations

`gpbackup` and `gprestore` have the following limitations:

If you create an index on a parent partitioned table, `gpbackup` does not back up that same index on child partitioned tables of the parent, as creating the same index on a child would cause an error. However, if you exchange a partition, `gpbackup` does not detect that the index on the exchanged partition is inherited from the new parent table. In this case, `gpbackup` backs up conflicting CREATE INDEX statements, which causes an error when you restore the backup set.

You can execute multiple instances of `gpbackup`, but each execution requires a distinct timestamp.

Database object filtering is currently limited to schemas and tables.

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When backing up a partitioned table where some or all leaf partitions are in different schemas from the root partition, the leaf partition table definitions, including the schemas, are backed up as metadata. This occurs even if the backup operation specifies that schemas that contain the leaf partitions should be excluded. To control data being backed up for this type of partitioned table in this situation, use the `--leaf-partition-data` option.

If the `--leaf-partition-data` option is not specified, the leaf partition data is also backed up even if the backup operation specifies that the leaf partition schemas should excluded. If the `--leaf-partition-data` option is specified, the leaf partition data is not be backed up if the backup operation specifies that the leaf partition schemas should excluded. Only the metadata for leaf partition tables are backed up. If you use the `gpbackup` --single-data-file option to combine table backups into a single file per segment, you cannot perform a parallel restore operation with `gprestore` (cannot set --jobs to a value higher than 1).

You cannot use the `--exclude-table-file` with `--leaf-partition-data`. Although you can specify leaf partition names in a file specified with `--exclude-table-file`, `gpbackup` ignores the partition names.

Backing up a database with `gpbackup` while simultaneously running DDL commands might cause `gpbackup` to fail, in order to ensure consistency within the backup set. For example, if a table is dropped after the start of the backup operation, `gpbackup` exits and displays the error message ERROR: relation `<schema.table>` does not exist.

`gpbackup` might fail when a table is dropped during a backup operation due to table locking issues. `gpbackup` generates a list of tables to back up and acquires an ACCESS SHARED lock on the tables. If an `EXCLUSIVE LOCK` is held on a table, `gpbackup` acquires the `ACCESS SHARED` lock after the existing lock is released. If the table no longer exists when `gpbackup` attempts to acquire a lock on the table, `gpbackup` exits with the error message.

For tables that might be dropped during a backup, you can exclude the tables from a backup with a `gpbackup` table filtering option such as `--exclude-table` or --exclude-schema.

A backup created with `gpbackup` can only be restored to a WarehousePG cluster with the same number of segment instances as the source cluster. If you run gpexpand to add segments to the cluster, backups you made before starting the expand cannot be restored after the expansion has completed.

Parent topic: WarehousePG Administrator Guide

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4.12.1 Incremental Backups using gpbackup and gprestore

> **Associated Topics**
>
> - gpbackup & gprestore user guide
> - gpbackup syntax reference
> - gprestore syntax reference

The gpbackup and gprestore utilities support creating incremental backups of append-optimized tables and restoring from incremental backups. An incremental backup backs up all specified heap tables and backs up append-optimized tables (including append-optimized, column-oriented tables) only if the tables have changed.

For example, if a row of an append-optimized table has changed, the table is backed up. For partitioned append-optimized tables, only the changed leaf partitions are backed up.

Incremental backups are efficient when the total amount of data in append-optimized tables or table partitions that changed is small compared to the data that has not changed since the last backup.

An incremental backup backs up an append-optimized table only if one of the following operations was performed on the table after the last full or incremental backup:

- `ALTER TABLE`
- `DELETE`
- `INSERT`
- `TRUNCATE`
- `UPDATE`
- `DROP` and then re-create the table

Restoring data from incremental backups requires a complete incremental backup file set.

Understanding Incremental Backup Sets

An incremental backup set includes the following backups:

- A full backup. This is the full backup that the incremental backups are based on.
- The set of incremental backups that capture the changes to the database from the time of the full backup.

For example, you can create a full backup (Sunday) and then create three daily incremental backups(Monday, Wednesday, Friday). The full backup and all three incremental backups are the backup set.

> **Incremental Backup Set**
>
> - Full: Sunday
> - Incremental: Monday
> - Incremental: Wednesday
> - Incremental: Friday

When you create or add to an incremental backup set, `gpbackup` ensures that the backups in the set are created with a consistent set of backup options to ensure that the backup set can be used in a restore operation.

When you create an incremental backup you include these options with the other `gpbackup` options to create a backup:

`--leaf-partition-data`

- Required for all backups in the incremental backup set.
- Required when you create a full backup that will be the base backup for an incremental backup set.

`--incremental`

- Required when you create an incremental backup.

> **Note**
>
> `--data-only` and `--metadata-only` are not compatible with the `--incremental` option

`--from-timestamp`

- Optional. This option can be used with `--incremental`. The timestamp you specify if of an existing backup. The timestamp can be either an incremental backup or the initial full backup of the set.

The backup being created must be have the same command line options as the with the backup specified with the `--from-timestamp` option.

If you do not specify `--from-timestamp`, `gpbackup` attempts to find a compatible backup based on information in the `gpbackup` history database.

When you add an incremental backup to a backup set, `gpbackup` ensures that the full backup and the incremental backups are consistent by checking these `gpbackup` options:

`--dbname` - The database must be the same.

`--backup-dir` - The directory must be the same. The backup set, the

full backup and the incremental backups, must be in the same location.

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`--single-data-file` - This option must be either specified or absent

for all backups in the set.

`--plugin-config` - If this option is specified, it must be specified

for all backups in the backup set. The configuration must reference the same plugin binary.

`--include-table-file` , `--include-schema` , or any other

options that filter tables and schemas must be the same.

When checking schema filters, only the schema names are checked, not the objects contained in the schemas.

`--no-compression` - If this option is specified, it must be specified

for all backups in the backup set.

If compression is used on the on the full backup, compression must be used on the incremental backups. Different compression levels are allowed for the backups in the backup set. For a backup, the default is compression level 1.

> **Warning**
>
> If you try to add an `--incremental` backup to a backup set, the backup operation fails if the `gpbackup` command line options options are not consistent.

> **Associated Topics**
>
> - gpbackup & gprestore user guide
> - gpbackup syntax reference
> - gprestore syntax reference

Examples

The following example shows a backup strategy using weekly Full + daily Incremental backups.

The following command creates the first full backup of the backup set:

Sunday

```
$ gpbackup --dbname ww_sales --backup-dir /nfsmount/whpg_backups/ww_sales --leaf-partition-data
```

Resulting in the example backup set

```
20250518010000 (full backup, Sunday 1am)
```

> **Tip**
>
> Each backup has a timestamp taken when the backup is created, and is used in the naming of the backup set files.
>
> `YYYYMMDDhhmmss` is the format.
>
> For example, a backup on May 18,2025 at 1:00:00am local time, the backup file names contain `20250527` for the day and `010000` representing 1:00:00am.
>
> Resulting in a naming convention of `20250518010000` for the backup file set
>
> When you specify the `--backup-dir` option, the backups are created in the corresponding directory on each WarehousePG host, `/nfsmount/whpg_backups/ww_sales` in this example.

The next backup will be an incremental backup, based on the full backup above

Monday

```
$ gpbackup --dbname ww_sales --incremental --backup-dir /nfsmount/whpg_backups/ww_sales --leaf-partition-data
```

Resulting in a second backup belonging to the backup set.

```
20250518010000 (full backup, Sunday 1am)
20250519020000 (incremental backup, Monday 2am)
```

Subsequent backups are run on

- **Tuesday**
- **Wednesday**
- **Thursday**
- **Friday**
- **Saturday**

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resulting in this complete set.

```
20250518010000 (full backup, Sunday 1am)
20250519020000 (incremental backup, Monday 2am)
20250520030000 (incremental backup, Tuesday 3am)
20250521040000 (incremental backup, Wedndesday 4am)
20250522050000 (incremental backup, Thursday 5am)
20250523060000 (incremental backup, Friday 6am)
20250524070000 (incremental backup, Saturday 7am)
```

Full vs Incremental Backup Strategy

The advantage of Full backups is that they contain every object in the database, allowing for a simple restore (filtered, or complete). One disadvantage may be the size & duration of this backup.

Incremental backups decrease the time and volume of data backed up, but they will backup `HEAP` tables every time. To mitigate this, using a partitioned `AO/CO` table approach will greatly reduce incremental backups to only those partitions which have seen changes since the previous backup.

Given the Sunday-Saturday example above, the user has a choice of how to handle the next round of backups.

Weekly Full Backup + Incrementals Example

The user / DBA may choose to run a full backup again on Sunday (no `--incremental` flag)

```
$ gpbackup --dbname ww_sales --backup-dir /nfsmount/whpg_backups/ww_sales --leaf-partition-data
```

Resulting in a new full backup.

```
20250518010000 (full backup, Sunday 1am)
20250519020000 (incremental backup, Monday 2am)
20250520030000 (incremental backup, Tuesday 3am)
20250521040000 (incremental backup, Wedndesday 4am)
20250522050000 (incremental backup, Thursday 5am)
20250523060000 (incremental backup, Friday 6am)
20250524070000 (incremental backup, Saturday 7am)
20250525010000 (full backup, Sunday 1am)
```

The choice then could be made to retain the prior seven backups, or purge the data to convserve disk space.

Aggregated Incrementals Example using --from-timestamp

An alternative approach would be to take an incremental backup on the next Sunday using `--from-timestamp` which creates a single incremental backup set from the basis of the initial full backup on the previous Sunday.

For example:

```
$ gpbackup --dbname ww_sales --incremental --from-timestamp 20250518010000 --backup-dir /nfsmount/whpg_backups/ww_sales --leaf-partition-data
```

Resulting in the following backup sets

```
20250518010000 (full backup, Sunday 1am)
20250519020000 (incremental backup, Monday 2am)
20250520030000 (incremental backup, Tuesday 3am)
20250521040000 (incremental backup, Wedndesday 4am)
20250522050000 (incremental backup, Thursday 5am)
20250523060000 (incremental backup, Friday 6am)
20250524070000 (incremental backup, Saturday 7am)
20250525010000 (incremental backup, Sunday 1am)
```

While this last backup was incremental, it was incremental from the last full backup's timestamp.
This means all the previous incremental backup sets are now redundant, and not required.

> **redundant backup sets**
>
> These backup sets can now be deleted to reclaim storage space
>
> ```
> 20250519020000 (incremental backup, Monday 2am)
> 20250520030000 (incremental backup, Tuesday 3am)
> 20250521040000 (incremental backup, Wedndesday 4am)
> 20250522050000 (incremental backup, Thursday 5am)
> 20250523060000 (incremental backup, Friday 6am)
> 20250524070000 (incremental backup, Saturday 7am)
> ```

Resulting in the following two backups covering the entire week

```
20250518010000 (full backup, Sunday 1am)
20250525010000 (incremental backup, Sunday 1am)
```

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Restoring Incremental Backup Sets

Based on the previous examples of full and incremental backups

```
20250518010000 (full backup, Sunday 1am)
20250519020000 (incremental backup, Monday 2am)
20250520030000 (incremental backup, Tuesday 3am)
20250521040000 (incremental backup, Wedndesday 4am)
20250522050000 (incremental backup, Thursday 5am)
20250523060000 (incremental backup, Friday 6am)
20250524070000 (incremental backup, Saturday 7am)
```

The following `gprestore` command specifies the timestamp `20250521040000` (Wednesday) as the restore to point.

```
$ gprestore --timestamp 20250521040000 --redirect-db www_sales_pitr --create-db
```

The incremental backup with the timestamps

- `20250520030000` (Tuesday)
- `20250519020000` (Monday)

And the full backup

- `20250518010000` (Sunday)

must be available to perform a succesful restore.

Tips & Notes

> **Choices**
>
> - The amount of backups (full or incremental) retained is a choice for each user. Some enterprises may have regulatory requirements to keep `x of days` of backups.
> - `RPO` (Recovery Point Objective) 1 day, 1 week, 1 month for example, may play a role in how you develop your backup strategy.
> - Using `--incremental` backups, effective partitioning of `AO/CO` tables, and the use of the `--include` and `--exclude` table and schema filters, allow for a flexible and performant approach to your backup strategy.

To create an incremental backup, or to restore data from an incremental backup set, you need the complete backup set. When you archive incremental backups, the complete backup set must be archived. You must archive all the files created on the coordinator and all segments.

Each time `gpbackup` runs, the utility adds backup information to the backup history database `gpbackup_history.db` located in the WarehousePG `$COORDINATORY_DATA_DIRECTORY`. This sqlite database contains metadata details of the backup set, such as timestamp, flags used, object contents. To bypass the inserting of this metadata into the history database, the `--no-history` flag can be included in your `gpbakcup` command.

When using the `--incremental` flag without the `--from-timestamp` option, `gpbackup` will attempt to find the most recent backup with the same command line options, in the `gpbackup_history.db`. If `gpbackup` cannot find a backup with a consistent set of options, `gpbackup` displays a warning indicating a full backup must be created before an incremental can be created.

When using the `--from-timestamp` option with `--incremental`, `gpbackup` ensures that the command line options of the current backup match the options of the previously created incremental backup with the specified timestamp.

The `gpbackup` option `--with-stats` is not required to be the same for all backups in the backup set. However, to perform a restore operation with the `gprestore` option `--with-stats` to restore statistics, the backup you specify must have must have used the `--with-stats` when taking the backup.

Restore operations can be performed from any backup in the backup set. However, changes captured in incremental backups later than the backup use to restore database data will not be restored.

When restoring from an incremental backup set, `gprestore` checks the backups and restores each append-optimized table from the most recent version of the append-optimized table in the backup set.

Heap tables are always restored from the latest backup in the incremental backup set.

The incremental back up set, a full backup and associated incremental backups, must be on a single device. For example, the backups in a backup set must all be on the local filesystem, S3 compatible bucket or a NFS mount point accessible my all hosts in the WarehousePG cluster.

> **Warning**
>
> Changes to the WarehousePG segment configuration invalidate incremental backups. After you change the segment configuration (add or remove segment instances), you must create a full backup before you can create an incremental backup.

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5 WarehousePG security configuration guide

This guide describes how to secure a WarehousePG cluster. The guide assumes knowledge of Linux/UNIX system administration and database management systems. Familiarity with structured query language (SQL) is helpful.

> **Important** Because WarehousePG is based on PostgreSQL, certain commercial security scanning software, when trying to identify WarehousePG vulnerabilities, may use a PostgreSQL database profile. The reports generated by these tools can produce misleading results, and cannot be trusted as an accurate assessment of vulnerabilities that may exist in WarehousePG.

Because WarehousePG is based on PostgreSQL 9.4, this guide assumes some familiarity with PostgreSQL. References to PostgreSQL documentation are provided throughout this guide for features that are similar to those in WarehousePG.

This information is intended for system administrators responsible for administering a WarehousePG cluster.

- Securing the Database
  Introduces WarehousePG security topics.
- WarehousePG Ports and Protocols
  Lists network ports and protocols used within the WarehousePG cluster.
- Configuring Client Authentication
  Describes the available methods for authenticating WarehousePG clients.
- Configuring Database Authorization
  Describes how to restrict authorization access to database data at the user level by using roles and permissions.
- Auditing
  Describes WarehousePG events that are logged and should be monitored to detect security threats.
- Encrypting Data and Database Connections
  Describes how to encrypt data at rest in the database or in transit over the network, to protect from eavesdroppers or man-in-the-middle attacks.
- Security Best Practices
  Describes basic security best practices that you should follow to ensure the highest level of system security.

About Endpoint Security Software

If you install any endpoint security software on your WarehousePG hosts, such as anti-virus, data protection, network security, or other security related software, the additional CPU, IO, network or memory load can interfere with WarehousePG operations and may affect database performance and stability.

Refer to your endpoint security vendor and perform careful testing in a non-production environment to ensure it does not have any negative impact on WarehousePG operations.

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5.1 Securing the Database

Introduces WarehousePG security topics.

The intent of security configuration is to configure the WarehousePG server to eliminate as many security vulnerabilities as possible. This guide provides a baseline for minimum security requirements, and is supplemented by additional security documentation.

The essential security requirements fall into the following categories:

- Authentication covers the mechanisms that are supported and that can be used by the WarehousePG server to establish the identity of a client application.
- Authorization pertains to the privilege and permission models used by the database to authorize client access.
- Auditing, or log settings, covers the logging options available in WarehousePG to track successful or failed user actions.
- Data Encryption addresses the encryption capabilities that are available for protecting data at rest and data in transit. This includes the security certifications that are relevant to the WarehousePG.

Accessing a Kerberized Hadoop Cluster

You can use the WarehousePG Platform Extension Framework (PXF) to read or write external tables referencing files in a Hadoop file system. If the Hadoop cluster is secured with Kerberos ("Kerberized"), you must configure WarehousePG and PXF to allow users accessing external tables to authenticate with Kerberos. Refer to Configuring PXF for Secure HDFS for the procedure to perform this setup.

Platform Hardening

Platform hardening involves assessing and minimizing system vulnerability by following best practices and enforcing federal security standards. Hardening the product is based on the US Department of Defense (DoD) guidelines Security Template Implementation Guides (STIG). Hardening removes unnecessary packages, deactivates services that are not required, sets up restrictive file and directory permissions, removes unowned files and directories, performs authentication for single-user mode, and provides options for end users to configure the package to be compliant to the latest STIGs.

Parent topic: WarehousePG Security Configuration Guide

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5.2 WarehousePG Ports and Protocols

Lists network ports and protocols used within the WarehousePG cluster.

WarehousePG clients connect with TCP to the WarehousePG coordinator instance at the client connection port, 5432 by default. The listen port can be reconfigured in the postgresql.conf configuration file. Client connections use the PostgreSQL libpq API. The `psql` command-line interface, several WarehousePG utilities, and language-specific programming APIs all either use the libpq library directly or implement the libpq protocol internally.

Each segment instance also has a client connection port, used solely by the coordinator instance to coordinate database operations with the segments. The `gpstate -p` command, run on the WarehousePG coordinator, lists the port assignments for the WarehousePG coordinator and the primary segments and mirrors. For example:

```
[gpadmin@cdw ~]$ gpstate -p
20190403:02:57:04:011030 gpstate:cdw:gpadmin-[INFO]:-Starting gpstate with args: -p
20190403:02:57:05:011030 gpstate:cdw:gpadmin-[INFO]:-local WarehousePG Version: 'postgres (WarehousePG) 5.17.0 build
commit:fc9a9d4cad8dd4037b9bc07bf837c0b958726103'
20190403:02:57:05:011030 gpstate:cdw:gpadmin-[INFO]:-coordinator WarehousePG Version: 'PostgreSQL 8.3.23 (WarehousePG 5.17.0 build
commit:fc9a9d4cad8dd4037b9bc07bf837c0b958726103) on x86_64-pc-linux-gnu, compiled by GCC gcc (GCC) 6.2.0, 64-bit compiled on Feb 13 2019 15:26:34'
20190403:02:57:05:011030 gpstate:cdw:gpadmin-[INFO]:-Obtaining Segment details from coordinator...
20190403:02:57:05:011030 gpstate:cdw:gpadmin-[INFO]:--Coordinator segment instance  /data/coordinator/gpseg-1  port = 5432
20190403:02:57:05:011030 gpstate:cdw:gpadmin-[INFO]:--Segment instance port assignments
20190403:02:57:05:011030 gpstate:cdw:gpadmin-[INFO]:----------------------------------
20190403:02:57:05:011030 gpstate:cdw:gpadmin-[INFO]:-   Host   Datadir                Port
20190403:02:57:05:011030 gpstate:cdw:gpadmin-[INFO]:-   sdw1   /data/primary/gpseg0   20000
20190403:02:57:05:011030 gpstate:cdw:gpadmin-[INFO]:-   sdw2   /data/mirror/gpseg0    21000
20190403:02:57:05:011030 gpstate:cdw:gpadmin-[INFO]:-   sdw1   /data/primary/gpseg1   20001
20190403:02:57:05:011030 gpstate:cdw:gpadmin-[INFO]:-   sdw2   /data/mirror/gpseg1    21001
20190403:02:57:05:011030 gpstate:cdw:gpadmin-[INFO]:-   sdw1   /data/primary/gpseg2   20002
20190403:02:57:05:011030 gpstate:cdw:gpadmin-[INFO]:-   sdw2   /data/mirror/gpseg2    21002
20190403:02:57:05:011030 gpstate:cdw:gpadmin-[INFO]:-   sdw2   /data/primary/gpseg3   20000
20190403:02:57:05:011030 gpstate:cdw:gpadmin-[INFO]:-   sdw3   /data/mirror/gpseg3    21000
20190403:02:57:05:011030 gpstate:cdw:gpadmin-[INFO]:-   sdw2   /data/primary/gpseg4   20001
20190403:02:57:05:011030 gpstate:cdw:gpadmin-[INFO]:-   sdw3   /data/mirror/gpseg4    21001
20190403:02:57:05:011030 gpstate:cdw:gpadmin-[INFO]:-   sdw2   /data/primary/gpseg5   20002
20190403:02:57:05:011030 gpstate:cdw:gpadmin-[INFO]:-   sdw3   /data/mirror/gpseg5    21002
20190403:02:57:05:011030 gpstate:cdw:gpadmin-[INFO]:-   sdw3   /data/primary/gpseg6   20000
20190403:02:57:05:011030 gpstate:cdw:gpadmin-[INFO]:-   sdw1   /data/mirror/gpseg6    21000
20190403:02:57:05:011030 gpstate:cdw:gpadmin-[INFO]:-   sdw3   /data/primary/gpseg7   20001
20190403:02:57:05:011030 gpstate:cdw:gpadmin-[INFO]:-   sdw1   /data/mirror/gpseg7    21001
20190403:02:57:05:011030 gpstate:cdw:gpadmin-[INFO]:-   sdw3   /data/primary/gpseg8   20002
20190403:02:57:05:011030 gpstate:cdw:gpadmin-[INFO]:-   sdw1   /data/mirror/gpseg8    21002
```

Additional WarehousePG network connections are created for features such as standby replication, segment mirroring, statistics collection, and data exchange between segments. Some persistent connections are established when the database starts up and other transient connections are created during operations such as query execution. Transient connections for query execution processes, data movement, and statistics collection use available ports in the range 1025 to 65535 with both TCP and UDP protocols.

> **Note** To avoid port conflicts between WarehousePG and other applications when initializing WarehousePG, do not specify WarehousePG ports in the range specified by the operating system parameter `net.ipv4.ip_local_port_range`. For example, if `net.ipv4.ip_local_port_range = 10000 65535`, you could set the WarehousePG base port numbers to values outside of that range:

```
PORT_BASE = 6000
MIRROR_PORT_BASE = 7000
```

Some add-on products and services that work with WarehousePG have additional networking requirements. The following table lists ports and protocols used within the WarehousePG cluster, and includes services and applications that integrate with WarehousePG.

Service	Protocol/Port	Description
Coordinator SQL client connection	TCP 5432, libpq	SQL client connection port on the WarehousePG coordinator host. Supports clients using the PostgreSQL libpq API. Configurable.
Segment SQL client connection	varies, libpq	The SQL client connection port for a segment instance. Each primary and mirror segment on a host must have a unique port. Ports are assigned when the WarehousePG cluster is initialized or expanded. The `gp_segment_configuration` system catalog records port numbers for each primary (p) or mirror (m) segment in the `port` column. Run `gpstate -p` to view the ports in use.
Segment mirroring port	varies, libpq	The port where a segment receives mirrored blocks from its primary. The port is assigned when the mirror is set up. The `gp_segment_configuration` system catalog records port numbers for each primary (p) or mirror (m) segment in the `port` column. Run `gpstate -p` to view the ports in use.
WarehousePG Interconnect	UDP 1025-65535, dynamically allocated	The Interconnect transports database tuples between WarehousePG segments during query execution.
Standby coordinator client listener	TCP 5432, libpq	SQL client connection port on the standby coordinator host. Usually the same as the coordinator client connection port. Configure with the `gpinitstandby` utility `-P` option.
Standby coordinator replicator	TCP 1025-65535, gpsyncmaster	The `gpsyncmaster` process on the coordinator host establishes a connection to the secondary coordinator host to replicate the coordinator's log to the standby coordinator.
WarehousePG file load and transfer utilities: gpfdist, gpload.	TCP 8080, HTTP TCP 9000, HTTPS	The gpfdist file serving utility can run on WarehousePG hosts or external hosts. Specify the connection port with the `-p` option when starting the server. The gpload utility runs one or more instances of gpfdist with ports or port ranges specified in a configuration file.
Backup completion notification	TCP 25, TCP 587, SMTP	The `gpbackup` backup utility can optionally send email to a list of email addresses at completion of a backup. The SMTP service must be enabled on the WarehousePG coordinator host.
WarehousePG secure shell (SSH): gpssh, gpsync, gpssh-exkeys	TCP 22, SSH	Many WarehousePG utilities use rsync and ssh to transfer files between hosts and manage the WarehousePG cluster within the cluster.
WarehousePG Platform Extension Framework (PXF)	TCP 5888	The PXF Java service runs on port number 5888 on each WarehousePG segment host.

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Service	Protocol/Port	Description
Dell PowerProtect (Data Domain)	TCP/UDP 111, NFS portmapper	Used to assign a random port for the mountd service used by NFS. The mountd service port can be statically assigned on the Data Domain server.
Dell PowerProtect (Data Domain)	TCP 2052	Main port used by NFS mountd. This port can be set on the Data Domain system using the `nfs set mountd-port` command .
Dell PowerProtect (Data Domain)	TCP 2049, NFS	Main port used by NFS. This port can be configured using the `nfs set server-port` command on the Data Domain server.
Dell PowerProtect (Data Domain)	TCP 2051, replication	Used when replication is configured on the Data Domain system. This port can be configured using the `replication modify` command on the Data Domain server.
Pgbouncer connection pooler	TCP, libpq	The pgbouncer connection pooler runs between libpq clients and WarehousePG (or PostgreSQL) databases. While you can run it on the WarehousePG coordinator host, running pgbouncer on a host outside of the WarehousePG cluster is recommended. When it runs on a separate host, pgbouncer can act as a warm standby mechanism for the WarehousePG coordinator host, switching to the WarehousePG standby host without requiring clients to reconfigure. Set the client connection port and the WarehousePG coordinator host address and port in the pgbouncer.ini configuration file.

Parent topic: WarehousePG Security Configuration Guide

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5.3 Configuring Client Authentication

Describes the available methods for authenticating WarehousePG clients.

When a WarehousePG cluster is first initialized, the system contains one predefined superuser role. This role will have the same name as the operating system user who initialized the WarehousePG cluster. This role is referred to as gpadmin. By default, the system is configured to only allow local connections to the database from the gpadmin role. If you want to allow any other roles to connect, or if you want to allow connections from remote hosts, you have to configure WarehousePG to allow such connections. This section explains how to configure client connections and authentication to WarehousePG.

- Allowing Connections to WarehousePG
- Editing the pg_hba.conf File
- Authentication Methods
- Limiting Concurrent Connections
- Encrypting Client/Server Connections

Parent topic: WarehousePG Security Configuration Guide

Allowing Connections to WarehousePG

Client access and authentication is controlled by a configuration file named `pg_hba.conf` (the standard PostgreSQL host-based authentication file). For detailed information about this file, see The pg_hba.conf File in the PostgreSQL documentation.

In WarehousePG, the `pg_hba.conf` file of the coordinator instance controls client access and authentication to your WarehousePG cluster. The segments also have `pg_hba.conf` files, but these are already correctly configured to only allow client connections from the coordinator host. The segments never accept outside client connections, so there is no need to alter the `pg_hba.conf` file on segments.

The general format of the `pg_hba.conf` file is a set of records, one per line. Blank lines are ignored, as is any text after a # comment character. A record is made up of a number of fields which are separated by spaces and/or tabs. Fields can contain white space if the field value is quoted. Records cannot be continued across lines.

A record can have one of seven formats:

```
local      <database>  <user>  <auth-method>  [<auth-options>]
host       <database>  <user>  <address>  <auth-method>  [<auth-options>]
hostssl    <database>  <user>  <address>  <auth-method>  [<auth-options>]
hostnossl  <database>  <user>  <address>  <auth-method>  [<auth-options>]
host       <database>  <user>  <IP-address>  <IP-mask>  <auth-method>  [<auth-options>]
hostssl    <database>  <user>  <IP-address>  <IP-mask>  <auth-method>  [<auth-options>]
hostnossl  <database>  <user>  <IP-address>  <IP-mask>  <auth-method>  [<auth-options>]
```

The meaning of the `pg_hba.conf` fields is as follows:

`local` Matches connection attempts using UNIX-domain sockets. Without a record of this type, UNIX-domain socket connections are disallowed.

`host` Matches connection attempts made using TCP/IP. Remote TCP/IP connections will not be possible unless the server is started with an appropriate value for the `listen_addresses` server configuration parameter. WarehousePG by default allows connections from all hosts (`'*'`).

`hostssl` Matches connection attempts made using TCP/IP, but only when the connection is made with SSL encryption. SSL must be enabled at server start time by setting the `ssl` configuration parameter to on. Requires SSL authentication be configured in `postgresql.conf` . See Configuring postgresql.conf for SSL Authentication.

`hostnossl` Matches connection attempts made over TCP/IP that do not use SSL.

`database` Specifies which database names this record matches. The value `all` specifies that it matches all databases. Multiple database names can be supplied by separating them with commas. A separate file containing database names can be specified by preceding the file name with `@` .

`user` Specifies which database role names this record matches. The value `all` specifies that it matches all roles. If the specified role is a group and you want all members of that group to be included, precede the role name with a `+` . Multiple role names can be supplied by separating them with commas. A separate file containing role names can be specified by preceding the file name with `@` .

`address` Specifies the client machine addresses that this record matches. This field can contain either a host name, an IP address range, or one of the special key words mentioned below.

An IP address range is specified using standard numeric notation for the range's starting address, then a slash (`/`) and a CIDR mask length. The mask length indicates the number of high-order bits of the client IP address that must match. Bits to the right of this should be zero in the given IP address. There must not be any white space between the IP address, the `/` , and the CIDR mask length.

Typical examples of an IPv4 address range specified this way are `172.20.143.89/32` for a single host, or `172.20.143.0/24` for a small network, or `10.6.0.0/16` for a larger one. An IPv6 address range might look like `::1/128` for a single host (in this case the IPv6 loopback address) or `fe80::7a31:c1ff:0000:0000/96` for a small network. `0.0.0.0/0` represents all IPv4 addresses, and `::0/0` represents all IPv6 addresses. To specify a single host, use a mask length of 32 for IPv4 or 128 for IPv6. In a network address, do not omit trailing zeroes.

An entry given in IPv4 format will match only IPv4 connections, and an entry given in IPv6 format will match only IPv6 connections, even if the represented address is in the IPv4-in-IPv6 range.

> **Note** Entries in IPv6 format will be rejected if the host system C library does not have support for IPv6 addresses.

You can also write `all` to match any IP address, `samehost` to match any of the server's own IP addresses, or `samenet` to match any address in any subnet to which the server is directly connected.

If a host name is specified (an address that is not an IP address, IP range, or special key word is treated as a host name), that name is compared with the result of a reverse name resolution of the client IP address (for example, reverse DNS lookup, if DNS is used). Host name comparisons are case insensitive. If there is a match, then a forward name resolution (for example, forward DNS lookup) is performed on the host name to check whether any of the addresses it resolves to are equal to the client IP address. If both directions match, then the entry is considered to match.

The host name that is used in `pg_hba.conf` should be the one that address-to-name resolution of the client's IP address returns, otherwise the line won't be matched. Some host name databases allow associating an IP address with multiple host names, but the operating system will only return one host name when asked to resolve an IP address.

A host name specification that starts with a dot (.) matches a suffix of the actual host name. So `.example.com` would match `foo.example.com` (but not just `example.com`).

When host names are specified in `pg_hba.conf` , you should ensure that name resolution is reasonably fast. It can be advantageous to set up a local name resolution cache such as `nscd` . Also, you can enable the server configuration parameter `log_hostname` to see the client host name instead of the IP address in the log.

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`IP-address` `IP-mask` These two fields can be used as an alternative to the CIDR address notation. Instead of specifying the mask length, the actual mask is specified in a separate column. For example, `255.0.0.0` represents an IPv4 CIDR mask length of 8, and `255.255.255.255` represents a CIDR mask length of 32.

`auth-method` Specifies the authentication method to use when a connection matches this record. See Authentication Methods for options.

`auth-options` After the `auth-method` field, there can be field(s) of the form `name=value` that specify options for the authentication method. Details about which options are available for which authentication methods are described in Authentication Methods.

Files included by @ constructs are read as lists of names, which can be separated by either whitespace or commas. Comments are introduced by #, just as in `pg_hba.conf`, and nested @ constructs are allowed. Unless the file name following @ is an absolute path, it is taken to be relative to the directory containing the referencing file.

The `pg_hba.conf` records are examined sequentially for each connection attempt, so the order of the records is significant. Typically, earlier records will have tight connection match parameters and weaker authentication methods, while later records will have looser match parameters and stronger authentication methods. For example, you might wish to use `trust` authentication for local TCP/IP connections but require a password for remote TCP/IP connections. In this case a record specifying `trust` authentication for connections from 127.0.0.1 would appear before a record specifying `password` authentication for a wider range of allowed client IP addresses.

The `pg_hba.conf` file is read on start-up and when the main server process receives a SIGHUP signal. If you edit the file on an active system, you must reload the file using this command:

```
$ gpstop -u
```

CAUTION: For a more secure system, remove records for remote connections that use `trust` authentication from the `pg_hba.conf` file. `trust` authentication grants any user who can connect to the server access to the database using any role they specify. You can safely replace `trust` authentication with `ident` authentication for local UNIX-socket connections. You can also use `ident` authentication for local and remote TCP clients, but the client host must be running an ident service and you must `trust` the integrity of that machine.

Editing the pg_hba.conf File

Initially, the `pg_hba.conf` file is set up with generous permissions for the gpadmin user and no database access for other WarehousePG roles. You will need to edit the `pg_hba.conf` file to enable users' access to databases and to secure the gpadmin user. Consider removing entries that have `trust` authentication, since they allow anyone with access to the server to connect with any role they choose. For local (UNIX socket) connections, use `ident` authentication, which requires the operating system user to match the role specified. For local and remote TCP connections, `ident` authentication requires the client's host to run an indent service. You could install an ident service on the coordinator host and then use `ident` authentication for local TCP connections, for example `127.0.0.1/28`. Using `ident` authentication for remote TCP connections is less secure because it requires you to trust the integrity of the ident service on the client's host.

This example shows how to edit the `pg_hba.conf` file on the coordinator host to allow remote client access to all databases from all roles using encrypted password authentication.

To edit `pg_hba.conf`:

1. Open the file `$COORDINATOR_DATA_DIRECTORY/pg_hba.conf` in a text editor.
2. Add a line to the file for each type of connection you want to allow. Records are read sequentially, so the order of the records is significant. Typically, earlier records will have tight connection match parameters and weaker authentication methods, while later records will have looser match parameters and stronger authentication methods. For example:

   ```
   # allow the gpadmin user local access to all databases
   # using ident authentication
   local   all   gpadmin   ident         sameuser
   host    all   gpadmin   127.0.0.1/32  ident
   host    all   gpadmin   ::1/128       ident
   # allow the 'dba' role access to any database from any
   # host with IP address 192.168.x.x and use md5 encrypted
   # passwords to authenticate the user
   # Note that to use SHA-256 encryption, replace md5 with
   # password in the line below
   host    all   dba   192.168.0.0/32  md5
   ```

Authentication Methods

- Basic Authentication
- GSSAPI Authentication
- LDAP Authentication
- SSL Client Authentication
- PAM-Based Authentication
- Radius Authentication

Basic Authentication

Trust Allows the connection unconditionally, without the need for a password or any other authentication. This entry is required for the `gpadmin` role, and for WarehousePG utilities (for example `gpinitsystem`, `gpstop`, or `gpstart` amongst others) that need to connect between nodes without prompting for input or a password.

> **Important** For a more secure system, remove records for remote connections that use `trust` authentication from the `pg_hba.conf` file. `trust` authentication grants any user who can connect to the server access to the database using any role they specify. You can safely replace `trust` authentication with `ident` authentication for local UNIX-socket connections. You can also use `ident` authentication for local and remote TCP clients, but the client host must be running an ident service and you must `trust` the integrity of that machine.

Reject Reject the connections with the matching parameters. You should typically use this to restrict access from specific hosts or insecure connections.

Ident Authenticates based on the client's operating system user name. This is secure for local socket connections. Using `ident` for TCP connections from remote hosts requires that the client's host is running an ident service. The `ident` authentication method should only be used with remote hosts on a trusted, closed network.

md5 Require the client to supply a double-MD5-hashed password for authentication.

password Require the client to supply an unencrypted password for authentication. Since the password is sent in clear text over the network, this should not be used on untrusted networks.

The password-based authentication methods are `md5` and `password`. These methods operate similarly except for the way that the password is sent across the connection: MD5-hashed and clear-text respectively.

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If you are at all concerned about password "sniffing" attacks then `md5` is preferred. Plain `password` should always be avoided if possible. If the connection is protected by SSL encryption then `password` can be used safely (although SSL certificate authentication might be a better choice if you are depending on using SSL).

Following are some sample `pg_hba.conf` basic authentication entries:

```
hostnossl    all   all        0.0.0.0   reject
hostssl      all   testuser   0.0.0.0/0 md5
local        all   gpuser               ident
```

Or:

```

local    all           gpadmin         ident
host     all           gpadmin         localhost      trust
host     all           gpadmin         cdw            trust
local    replication   gpadmin         ident
host     replication   gpadmin         samenet       trust
host     all           all             0.0.0.0/0     md5
```

GSSAPI Authentication

GSSAPI is an industry-standard protocol for secure authentication defined in RFC 2743. WarehousePG supports GSSAPI with Kerberos authentication according to RFC 1964. GSSAPI provides automatic authentication (single sign-on) for systems that support it. The authentication itself is secure, but the data sent over the database connection will be sent unencrypted unless SSL is used.

The `gss` authentication method is only available for TCP/IP connections.

When GSSAPI uses Kerberos, it uses a standard principal in the format `servicename/hostname@realm`. The WarehousePG server will accept any principal that is included in the keytab file used by the server, but care needs to be taken to specify the correct principal details when making the connection from the client using the `krbsrvname` connection parameter. (See Connection Parameter Key Words in the PostgreSQL documentation.) In most environments, this parameter never needs to be changed. Some Kerberos implementations might require a different service name, such as Microsoft Active Directory, which requires the service name to be in upper case (POSTGRES).

`hostname` is the fully qualified host name of the server machine. The service principal's realm is the preferred realm of the server machine.

Client principals must have their WarehousePG user name as their first component, for example `gpusername@realm`. Alternatively, you can use a user name mapping to map from the first component of the principal name to the database user name. By default, WarehousePG does not check the realm of the client. If you have cross-realm authentication enabled and need to verify the realm, use the `krb_realm` parameter, or enable `include_realm` and use user name mapping to check the realm.

Make sure that your server keytab file is readable (and preferably only readable) by the `gpadmin` server account. The location of the key file is specified by the krb_server_keyfile configuration parameter. For security reasons, it is recommended to use a separate keytab just for the WarehousePG server rather than opening up permissions on the system keytab file.

The keytab file is generated by the Kerberos software; see the Kerberos documentation for details. The following example is for MIT-compatible Kerberos 5 implementations:

```
kadmin% **ank -randkey postgres/server.my.domain.org**
kadmin% **ktadd -k krb5.keytab postgres/server.my.domain.org**
```

When connecting to the database make sure you have a ticket for a principal matching the requested database user name. For example, for database user name `fred`, principal `fred@EXAMPLE.COM` would be able to connect. To also allow principal `fred/users.example.com@EXAMPLE.COM`, use a user name map, as described in User Name Maps in the PostgreSQL documentation.

The following configuration options are supported for GSSAPI:

`include_realm` If set to 1, the realm name from the authenticated user principal is included in the system user name that is passed through user name mapping. This is the recommended configuration as, otherwise, it is impossible to differentiate users with the same username who are from different realms. The default for this parameter is 0 (meaning to not include the realm in the system user name) but may change to 1 in a future version of WarehousePG. You can set it explicitly to avoid any issues when upgrading.

`map` Allows for mapping between system and database user names. For a GSSAPI/Kerberos principal, such as `username@EXAMPLE.COM` (or, less commonly, `username/hostbased@EXAMPLE.COM`), the default user name used for mapping is `username` (or `username/hostbased`, respectively), unless `include_realm` has been set to 1 (as recommended, see above), in which case `username@EXAMPLE.COM` (or `username/hostbased@EXAMPLE.COM`) is what is seen as the system username when mapping.

`krb_realm` Sets the realm to match user principal names against. If this parameter is set, only users of that realm will be accepted. If it is not set, users of any realm can connect, subject to whatever user name mapping is done.

LDAP Authentication

You can authenticate against an LDAP directory.

- LDAPS and LDAP over TLS options encrypt the connection to the LDAP server.
- The connection from the client to the server is not encrypted unless SSL is enabled. Configure client connections to use SSL to encrypt connections from the client.
- To configure or customize LDAP settings, set the `LDAPCONF` environment variable with the path to the `ldap.conf` file and add this to the `greenplum_path.sh` script.

Following are the recommended steps for configuring your system for LDAP authentication:

1. Set up the LDAP server with the database users/roles to be authenticated via LDAP.
2. On the database:
    1. Verify that the database users to be authenticated via LDAP exist on the database. LDAP is only used for verifying username/password pairs, so the roles should exist in the database.
    2. Update the `pg_hba.conf` file in the `$COORDINATOR_DATA_DIRECTORY` to use LDAP as the authentication method for the respective users. Note that the first entry to match the user/role in the `pg_hba.conf` file will be used as the authentication mechanism, so the position of the entry in the file is important.
    3. Reload the server for the `pg_hba.conf` configuration settings to take effect (`gpstop -u`).

Specify the following parameter `auth-options`.

ldapserver Names or IP addresses of LDAP servers to connect to. Multiple servers may be specified, separated by spaces.

ldapprefix String to prepend to the user name when forming the DN to bind as, when doing simple bind authentication.

ldapsuffix String to append to the user name when forming the DN to bind as, when doing simple bind authentication.

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ldapport Port number on LDAP server to connect to. If no port is specified, the LDAP library's default port setting will be used.

ldaptls Set to 1 to make the connection between PostgreSQL and the LDAP server use TLS encryption. Note that this only encrypts the traffic to the LDAP server — the connection to the client will still be unencrypted unless SSL is used.

ldapbasedn Root DN to begin the search for the user in, when doing search+bind authentication.

ldapbinddn DN of user to bind to the directory with to perform the search when doing search+bind authentication.

ldapbindpasswd Password for user to bind to the directory with to perform the search when doing search+bind authentication.

ldapsearchattribute Attribute to match against the user name in the search when doing search+bind authentication.

ldapsearchfilter Beginning with WarehousePG 6.22, this attribute enables you to provide a search filter to use when doing search+bind authentication. Occurrences of `$username` will be replaced with the user name. This allows for more flexible search filters than `ldapsearchattribute`. Note that you can specify *either* `ldapsearchattribute` or `ldapsearchattribute`, but not both.

When using search+bind mode, the search can be performed using a single attribute specified with `ldapsearchattribute`, or using a custom search filter specified with `ldapsearchfilter`. Specifying `ldapsearchattribute=foo` is equivalent to specifying `ldapsearchfilter="(foo=$username)"`. If neither option is specified the default is `ldapsearchattribute=uid`.

Here is an example for a search+bind configuration that uses `ldapsearchfilter` instead of `ldapsearchattribute` to allow authentication by user ID or email address:

```
host ... ldap ldapserver=ldap.example.net ldapbasedn="dc=example, dc=net" ldapsearchfilter="(|(uid=$username)(mail=$username))"
```

Following are additional sample `pg_hba.conf` file entries for LDAP authentication:

```
host all testuser 0.0.0.0/0 ldap ldap
ldapserver=ldapserver.greenplum.com ldapport=389 ldapprefix="cn=" ldapsuffix=",ou=people,dc=greenplum,dc=com"
hostssl   all   ldaprole   0.0.0.0/0   ldap
ldapserver=ldapserver.greenplum.com ldaptls=1 ldapprefix="cn=" ldapsuffix=",ou=people,dc=greenplum,dc=com"
```

SSL Client Authentication

SSL authentication compares the Common Name (cn) attribute of an SSL certificate provided by the connecting client during the SSL handshake to the requested database user name. The database user should exist in the database. A map file can be used for mapping between system and database user names.

SSL Authentication Parameters

Authentication method:

- Cert

  Authentication options:

  Hostssl Connection type must be hostssl.

  map=mapping mapping.

  This is specified in the `pg_ident.conf`, or in the file specified in the `ident_file` server setting.

  Following are sample `pg_hba.conf` entries for SSL client authentication:

  ```
  Hostssl testdb certuser 192.168.0.0/16 cert
  Hostssl testdb all 192.168.0.0/16 cert map=gpuser
  ```

OpenSSL Configuration

You can make changes to the OpenSSL configuration by updating the `openssl.cnf` file under your OpenSSL installation directory, or the file referenced by `$OPENSSL_CONF`, if present, and then restarting the WarehousePG server.

Creating a Self-Signed Certificate

A self-signed certificate can be used for testing, but a certificate signed by a certificate authority (CA) (either one of the global CAs or a local one) should be used in production so that clients can verify the server's identity. If all the clients are local to the organization, using a local CA is recommended.

To create a self-signed certificate for the server:

1. Enter the following `openssl` command:

   ```
   openssl req -new -text -out server.req
   ```

2. Enter the requested information at the prompts.

   Make sure you enter the local host name for the Common Name. The challenge password can be left blank.

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3. The program generates a key that is passphrase-protected; it does not accept a passphrase that is less than four characters long. To remove the passphrase (and you must if you want automatic start-up of the server), run the following command:

```
openssl rsa -in privkey.pem -out server.key
rm privkey.pem
```

4. Enter the old passphrase to unlock the existing key. Then run the following command:

```
openssl req -x509 -in server.req -text -key server.key -out server.crt
```

   This turns the certificate into a self-signed certificate and copies the key and certificate to where the server will look for them.

5. Finally, run the following command:

```
chmod og-rwx server.key
```

For more details on how to create your server private key and certificate, refer to the OpenSSL documentation.

Configuring postgresql.conf for SSL Authentication

The following Server settings need to be specified in the `postgresql.conf` configuration file:

- `ssl` *boolean*. Enables SSL connections.
- `ssl_renegotiation_limit` *integer*. Specifies the data limit before key renegotiation.
- `ssl_ciphers` *string*. Configures the list SSL ciphers that are allowed. `ssl_ciphers` *overrides* any ciphers string specified in `/etc/openssl.cnf`. The default value `ALL:!ADH:!LOW:!EXP:!MD5:@STRENGTH` enables all ciphers except for ADH, LOW, EXP, and MD5 ciphers, and prioritizes ciphers by their strength.

  > **Note** With TLS 1.2 some ciphers in MEDIUM and HIGH strength still use NULL encryption (no encryption for transport), which the default `ssl_ciphers` string allows. To bypass NULL ciphers with TLS 1.2 use a string such as `TLSv1.2:!eNULL:!aNULL`.

  It is possible to have authentication without encryption overhead by using `NULL-SHA` or `NULL-MD5` ciphers. However, a man-in-the-middle could read and pass communications between client and server. Also, encryption overhead is minimal compared to the overhead of authentication. For these reasons, NULL ciphers should not be used.

The default location for the following SSL server files is the WarehousePG coordinator data directory (`$COORDINATOR_DATA_DIRECTORY`):

- `server.crt` - Server certificate.
- `server.key` - Server private key.
- `root.crt` - Trusted certificate authorities.
- `root.crl` - Certificates revoked by certificate authorities.

If WarehousePG coordinator mirroring is enabled with SSL client authentication, the SSL server files *should not be placed* in the default directory `$COORDINATOR_DATA_DIRECTORY`. If a `gpinitstandby` operation is performed, the contents of `$COORDINATOR_DATA_DIRECTORY` is copied from the coordinator to the standby coordinator and the incorrect SSL key, and cert files (the coordinator files, and not the standby coordinator files) will prevent standby coordinator start up.

You can specify a different directory for the location of the SSL server files with the `postgresql.conf` parameters `sslcert`, `sslkey`, `sslrootcert`, and `sslcrl`.

Configuring the SSL Client Connection

SSL options:

sslmode Specifies the level of protection.

`require` Only use an SSL connection. If a root CA file is present, verify the certificate in the same way as if `verify-ca` was specified.

`verify-ca` Only use an SSL connection. Verify that the server certificate is issued by a trusted CA.

`verify-full` Only use an SSL connection. Verify that the server certificate is issued by a trusted CA and that the server host name matches that in the certificate.

sslcert The file name of the client SSL certificate. The default is `$COORDINATOR_DATA_DIRECTORY/postgresql.crt`.

sslkey The secret key used for the client certificate. The default is `$COORDINATOR_DATA_DIRECTORY/postgresql.key`.

sslrootcert The name of a file containing SSL Certificate Authority certificate(s). The default is `$COORDINATOR_DATA_DIRECTORY/root.crt`.

sslcrl The name of the SSL certificate revocation list. The default is `$COORDINATOR_DATA_DIRECTORY/root.crl`.

The client connection parameters can be set using the following environment variables:

- `sslmode` - `PGSSLMODE`
- `sslcert` - `PGSSLCERT`
- `sslkey` - `PGSSLKEY`
- `sslrootcert` - `PGSSLROOTCERT`
- `sslcrl` - `PGSSLCRL`

For example, run the following command to connect to the `postgres` database from `localhost` and verify the certificate present in the default location under `$COORDINATOR_DATA_DIRECTORY`:

```
psql "sslmode=verify-ca host=localhost dbname=postgres"
```

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PAM-Based Authentication

The "PAM" (Pluggable Authentication Modules) authentication method validates username/password pairs, similar to basic authentication. To use PAM authentication, the user must already exist as a WarehousePG role name.

WarehousePG uses the `pamservice` authentication parameter to identify the service from which to obtain the PAM configuration.

> **Note** If PAM is set up to read `/etc/shadow`, authentication will fail because the PostgreSQL server is started by a non-root user. This is not an issue when PAM is configured to use LDAP or another authentication method.

WarehousePG does not install a PAM configuration file. If you choose to use PAM authentication with WarehousePG, you must identify the PAM service name for WarehousePG and create the associated PAM service configuration file and configure WarehousePG to use PAM authentication as described below:

1. Log in to the WarehousePG coordinator host and set up your environment. For example:

   ```
   $ ssh gpadmin@<gpcoord>
   gpadmin@gpcoord$ . /usr/edb/whpg7/greenplum_path.sh
   ```

2. Identify the `pamservice` name for WarehousePG. In this procedure, we choose the name `greenplum`.

3. Create the PAM service configuration file, `/etc/pam.d/greenplum`, and add the text below. You must have operating system superuser privileges to create the `/etc/pam.d` directory (if necessary) and the `greenplum` PAM configuration file.

   ```
   #%PAM-1.0
   auth        include     password-auth
   account     include     password-auth
   ```

   This configuration instructs PAM to authenticate the local operating system user.

4. Ensure that the `/etc/pam.d/greenplum` file is readable by all users:

   ```
   sudo chmod 644 /etc/pam.d/greenplum
   ```

5. Add one or more entries to the `pg_hba.conf` configuration file to enable PAM authentication in WarehousePG. These entries must specify the `pam` *auth-method*. You must also specify the `pamservice=greenplum` *auth-option*. For example:

   ```
   host     <user-name>     <db-name>     <address>     pam     pamservice=greenplum
   ```

6. Reload the WarehousePG configuration:

   ```
   $ gpstop -u
   ```

Radius Authentication

RADIUS (Remote Authentication Dial In User Service) authentication works by sending an Access Request message of type 'Authenticate Only' to a configured RADIUS server. It includes parameters for user name, password (encrypted), and the Network Access Server (NAS) Identifier. The request is encrypted using the shared secret specified in the `radiussecret` option. The RADIUS server responds with either `Access Accept` or `Access Reject`.

> **Note** RADIUS accounting is not supported.

RADIUS authentication only works if the users already exist in the database.

The RADIUS encryption vector requires SSL to be enabled in order to be cryptographically strong.

RADIUS Authentication Options

radiusserver The name of the RADIUS server.

radiussecret The RADIUS shared secret.

radiusport The port to connect to on the RADIUS server.

radiusidentifier NAS identifier in RADIUS requests.

Following are sample `pg_hba.conf` entries for RADIUS client authentication:

```
hostssl  all all 0.0.0.0/0 radius radiusserver=servername radiussecret=sharedsecret
```

Limiting Concurrent Connections

To limit the number of active concurrent sessions to your WarehousePG cluster, you can configure the `max_connections` server configuration parameter. This is a local parameter, meaning that you must set it in the `postgresql.conf` file of the coordinator, the standby coordinator, and each segment instance (primary and mirror). The value of `max_connections` on segments must be 5-10 times the value on the coordinator.

When you set `max_connections`, you must also set the dependent parameter `max_prepared_transactions`. This value must be at least as large as the value of `max_connections` on the coordinator, and segment instances should be set to the same value as the coordinator.

In `$COORDINATOR_DATA_DIRECTORY/postgresql.conf` (including standby coordinator):

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```
max_connections=100
max_prepared_transactions=100
```

In `SEGMENT_DATA_DIRECTORY/postgresql.conf` for all segment instances:

```
max_connections=500
max_prepared_transactions=100
```

> **Note** Raising the values of these parameters may cause WarehousePG to request more shared memory. To mitigate this effect, consider decreasing other memory-related parameters such as `gp_cached_segworkers_threshold`.

To change the number of allowed connections:

1. Stop your WarehousePG cluster:

   ```
   $ gpstop
   ```

2. On the coordinator host, edit `$COORDINATOR_DATA_DIRECTORY/postgresql.conf` and change the following two parameters:

   - `max_connections` – the number of active user sessions you want to allow plus the number of `superuser_reserved_connections`.
   - `max_prepared_transactions` – must be greater than or equal to `max_connections`.

3. On each segment instance, edit `SEGMENT_DATA_DIRECTORY/postgresql.conf` and change the following two parameters:

   - `max_connections` – must be 5-10 times the value on the coordinator.
   - `max_prepared_transactions` – must be equal to the value on the coordinator.

4. Restart your WarehousePG cluster:

   ```
   $ gpstart
   ```

Encrypting Client/Server Connections

WarehousePG has native support for SSL connections between the client and the coordinator server. SSL connections prevent third parties from snooping on the packets, and also prevent man-in-the-middle attacks. SSL should be used whenever the client connection goes through an insecure link, and must be used whenever client certificate authentication is used.

> **Note** For information about encrypting data between the `gpfdist` server and WarehousePG segment hosts, see Encrypting gpfdist Connections.

To enable SSL requires that OpenSSL be installed on both the client and the coordinator server systems. WarehousePG can be started with SSL enabled by setting the server configuration parameter `ssl=on` in the coordinator `postgresql.conf`. When starting in SSL mode, the server will look for the files `server.key` (server private key) and `server.crt` (server certificate) in the coordinator data directory. These files must be set up correctly before an SSL-enabled WarehousePG cluster can start.

> **Important** Do not protect the private key with a passphrase. The server does not prompt for a passphrase for the private key, and the database startup fails with an error if one is required.

A self-signed certificate can be used for testing, but a certificate signed by a certificate authority (CA) should be used in production, so the client can verify the identity of the server. Either a global or local CA can be used. If all the clients are local to the organization, a local CA is recommended. See Creating a Self-Signed Certificate for steps to create a self-signed certificate.

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5.4 Configuring Database Authorization

Describes how to restrict authorization access to database data at the user level by using roles and permissions.

Parent topic: WarehousePG Security Configuration Guide

Access Permissions and Roles

WarehousePG manages database access permissions using *roles*. The concept of roles subsumes the concepts of users and groups. A role can be a database user, a group, or both. Roles can own database objects (for example, tables) and can assign privileges on those objects to other roles to control access to the objects. Roles can be members of other roles, thus a member role can inherit the object privileges of its parent role.

Every WarehousePG cluster contains a set of database roles (users and groups). Those roles are separate from the users and groups managed by the operating system on which the server runs. However, for convenience you may want to maintain a relationship between operating system user names and WarehousePG role names, since many of the client applications use the current operating system user name as the default.

In WarehousePG, users log in and connect through the coordinator instance, which verifies their role and access privileges. The coordinator then issues out commands to the segment instances behind the scenes using the currently logged in role.

Roles are defined at the system level, so they are valid for all databases in the system.

To bootstrap the WarehousePG cluster, a freshly initialized system always contains one predefined superuser role (also referred to as the system user). This role will have the same name as the operating system user that initialized the WarehousePG cluster. Customarily, this role is named `gpadmin`. To create more roles you first must connect as this initial role.

Managing Object Privileges

When an object (table, view, sequence, database, function, language, schema, or tablespace) is created, it is assigned an owner. The owner is normally the role that ran the creation statement. For most kinds of objects, the initial state is that only the owner (or a superuser) can do anything with the object. To allow other roles to use it, privileges must be granted. WarehousePG supports the following privileges for each object type:

Object Type	Privileges

Tables, Views, Sequences	`SELECT`
	`INSERT`
	`UPDATE`
	`DELETE`
	`RULE`
	`ALL`

External Tables	`SELECT`
	`RULE`
	`ALL`

Databases	`CONNECT`
	`CREATE`
	`TEMPORARY` or `TEMP`
	`ALL`

Functions	`EXECUTE`
Procedural Languages	`USAGE`

Schemas	`CREATE`
	`USAGE`
	`ALL`

Privileges must be granted for each object individually. For example, granting `ALL` on a database does not grant full access to the objects within that database. It only grants all of the database-level privileges (`CONNECT`, `CREATE`, `TEMPORARY`) to the database itself.

Use the `GRANT` SQL command to give a specified role privileges on an object. For example:

```
=# GRANT INSERT ON mytable TO jsmith;
```

To revoke privileges, use the `REVOKE` command. For example:

```
=# REVOKE ALL PRIVILEGES ON mytable FROM jsmith;
```

You can also use the `DROP OWNED` and `REASSIGN OWNED` commands for managing objects owned by deprecated roles. (Note: only an object's owner or a superuser can drop an object or reassign ownership.) For example:

```
=# REASSIGN OWNED BY sally TO bob;
=# DROP OWNED BY visitor;
```

Restricting Access by Time

WarehousePG enables the administrator to restrict access to certain times by role. Use the `CREATE ROLE` or `ALTER ROLE` commands to specify time-based constraints.

Access can be restricted by day or by day and time. The constraints are removable without deleting and recreating the role.

Time-based constraints only apply to the role to which they are assigned. If a role is a member of another role that contains a time constraint, the time constraint is not inherited.

Time-based constraints are enforced only during login. The `SET ROLE` and `SET SESSION AUTHORIZATION` commands are not affected by any time-based constraints.

Superuser or `CREATEROLE` privileges are required to set time-based constraints for a role. No one can add time-based constraints to a superuser.

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There are two ways to add time-based constraints. Use the keyword `DENY` in the `CREATE ROLE` or `ALTER ROLE` command followed by one of the following.

- A day, and optionally a time, when access is restricted. For example, no access on Wednesdays.
- An interval—that is, a beginning and ending day and optional time—when access is restricted. For example, no access from Wednesday 10 p.m. through Thursday at 8 a.m.

You can specify more than one restriction; for example, no access Wednesdays at any time and no access on Fridays between 3:00 p.m. and 5:00 p.m.

There are two ways to specify a day. Use the word `DAY` followed by either the English term for the weekday, in single quotation marks, or a number between 0 and 6, as shown in the table below.

English Term	Number
DAY 'Sunday'	DAY 0
DAY 'Monday'	DAY 1
DAY 'Tuesday'	DAY 2
DAY 'Wednesday'	DAY 3
DAY 'Thursday'	DAY 4
DAY 'Friday'	DAY 5
DAY 'Saturday'	DAY 6

A time of day is specified in either 12- or 24-hour format. The word `TIME` is followed by the specification in single quotation marks. Only hours and minutes are specified and are separated by a colon (:). If using a 12-hour format, add `AM` or `PM` at the end. The following examples show various time specifications.

```
TIME '14:00'     # 24-hour time implied
TIME '02:00 PM'  # 12-hour time specified by PM
TIME '02:00'     # 24-hour time implied. This is equivalent to TIME '02:00 AM'.
```

> **Important** Time-based authentication is enforced with the server time. Timezones are disregarded.

To specify an interval of time during which access is denied, use two day/time specifications with the words `BETWEEN` and `AND`, as shown. `DAY` is always required.

```
BETWEEN DAY 'Monday' AND DAY 'Tuesday'

BETWEEN DAY 'Monday' TIME '00:00' AND
        DAY 'Monday' TIME '01:00'

BETWEEN DAY 'Monday' TIME '12:00 AM' AND
        DAY 'Tuesday' TIME '02:00 AM'

BETWEEN DAY 'Monday' TIME '00:00' AND
        DAY 'Tuesday' TIME '02:00'
        DAY 2 TIME '02:00'
```

The last three statements are equivalent.

> **Note** Intervals of days cannot wrap past Saturday.

The following syntax is not correct:

```
DENY BETWEEN DAY 'Saturday' AND DAY 'Sunday'
```

The correct specification uses two DENY clauses, as follows:

```
DENY DAY 'Saturday'
DENY DAY 'Sunday'
```

The following examples demonstrate creating a role with time-based constraints and modifying a role to add time-based constraints. Only the statements needed for time-based constraints are shown. For more details on creating and altering roles see the descriptions of `CREATE ROLE` and `ALTER ROLE` in the *WarehousePG Reference Guide*.

Example 1 – Create a New Role with Time-based Constraints

No access is allowed on weekends.

```
CREATE ROLE generaluser
DENY DAY 'Saturday'
DENY DAY 'Sunday'
...
```

Example 2 – Alter a Role to Add Time-based Constraints

No access is allowed every night between 2:00 a.m. and 4:00 a.m.

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```
ALTER ROLE generaluser
 DENY BETWEEN DAY 'Monday' TIME '02:00' AND DAY 'Monday' TIME '04:00'
 DENY BETWEEN DAY 'Tuesday' TIME '02:00' AND DAY 'Tuesday' TIME '04:00'
 DENY BETWEEN DAY 'Wednesday' TIME '02:00' AND DAY 'Wednesday' TIME '04:00'
 DENY BETWEEN DAY 'Thursday' TIME '02:00' AND DAY 'Thursday' TIME '04:00'
 DENY BETWEEN DAY 'Friday' TIME '02:00' AND DAY 'Friday' TIME '04:00'
 DENY BETWEEN DAY 'Saturday' TIME '02:00' AND DAY 'Saturday' TIME '04:00'
 DENY BETWEEN DAY 'Sunday' TIME '02:00' AND DAY 'Sunday' TIME '04:00'
  ...
```

Excample 3 – Alter a Role to Add Time-based Constraints

No access is allowed Wednesdays or Fridays between 3:00 p.m. and 5:00 p.m.

```
ALTER ROLE generaluser
 DENY DAY 'Wednesday'
 DENY BETWEEN DAY 'Friday' TIME '15:00' AND DAY 'Friday' TIME '17:00'
```

Dropping a Time-based Restriction

To remove a time-based restriction, use the ALTER ROLE command. Enter the keywords DROP DENY FOR followed by a day/time specification to drop.

```
DROP DENY FOR DAY 'Sunday'
```

Any constraint containing all or part of the conditions in a DROP clause is removed. For example, if an existing constraint denies access on Mondays and Tuesdays, and the DROP clause removes constraints for Mondays, the existing constraint is completely dropped. The DROP clause completely removes all constraints that overlap with the constraint in the drop clause. The overlapping constraints are completely removed even if they contain more restrictions that the restrictions mentioned in the DROP clause.

Example 1 - Remove a Time-based Restriction from a Role

```
ALTER ROLE generaluser
DROP DENY FOR DAY 'Monday'
   ...
```

This statement would remove all constraints that overlap with a Monday constraint for the role `generaluser` in Example 2, even if there are additional constraints.

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5.5 Auditing

Describes WarehousePG events that are logged and should be monitored to detect security threats.

WarehousePG is capable of auditing a variety of events, including startup and shutdown of the system, segment database failures, SQL statements that result in an error, and all connection attempts and disconnections. WarehousePG also logs SQL statements and information regarding SQL statements, and can be configured in a variety of ways to record audit information with more or less detail. The `log_error_verbosity` configuration parameter controls the amount of detail written in the server log for each message that is logged. Similarly, the `log_min_error_statement` parameter allows administrators to configure the level of detail recorded specifically for SQL statements, and the `log_statement` parameter determines the kind of SQL statements that are audited. WarehousePG records the username for all auditable events, when the event is initiated by a subject outside the WarehousePG.

WarehousePG prevents unauthorized modification and deletion of audit records by only allowing administrators with an appropriate role to perform any operations on log files. Logs are stored in a proprietary format using comma-separated values (CSV). Each segment and the coordinator stores its own log files, although these can be accessed remotely by an administrator. WarehousePG also authorizes overwriting of old log files via the `log_truncate_on_rotation` parameter. This is a local parameter and must be set on each segment and coordinator configuration file.

WarehousePG provides an administrative schema called `gp_toolkit` that you can use to query log files, as well as system catalogs and operating environment for system status information. For more information, including usage, refer to *The gp_tookit Administrative Schema* appendix in the *WarehousePG Reference Guide*.

WarehousePG includes the PostgreSQL Audit Extension, or pgaudit, which provides detailed session and object audit logging via the standard logging facility provided by PostgreSQL. The goal of PostgreSQL Audit is to provide the tools needed to produce audit logs required to pass certain government, financial, or ISO certification audits.

Viewing the Database Server Log Files

Every database instance in WarehousePG (coordinator and segments) is a running PostgreSQL database server with its own server log file. Daily log files are created in the `log` directory of the coordinator and each segment data directory.

The server log files are written in comma-separated values (CSV) format. Not all log entries will have values for all of the log fields. For example, only log entries associated with a query worker process will have the `slice_id` populated. Related log entries of a particular query can be identified by its session identifier (`gp_session_id`) and command identifier (`gp_command_count`).

#	Field Name	Data Type	Description
1	event_time	timestamp with time zone	Time that the log entry was written to the log
2	user_name	varchar(100)	The database user name
3	database_name	varchar(100)	The database name
4	process_id	varchar(10)	The system process id (prefixed with "p")
5	thread_id	varchar(50)	The thread count (prefixed with "th")
6	remote_host	varchar(100)	On the coordinator, the hostname/address of the client machine. On the segment, the hostname/address of the coordinator.
7	remote_port	varchar(10)	The segment or coordinator port number
8	session_start_time	timestamp with time zone	Time session connection was opened
9	transaction_id	int	Top-level transaction ID on the coordinator. This ID is the parent of any subtransactions.
10	gp_session_id	text	Session identifier number (prefixed with "con")
11	gp_command_count	text	The command number within a session (prefixed with "cmd")
12	gp_segment	text	The segment content identifier (prefixed with "seg" for primaries or "mir" for mirrors). The coordinator always has a content id of -1.
13	slice_id	text	The slice id (portion of the query plan being run)
14	distr_tranx_id text	Distributed transaction ID	
15	local_tranx_id	text	Local transaction ID
16	sub_tranx_id	text	Subtransaction ID
17	event_severity	varchar(10)	Values include: LOG, ERROR, FATAL, PANIC, DEBUG1, DEBUG2
18	sql_state_code	varchar(10)	SQL state code associated with the log message
19	event_message	text	Log or error message text
20	event_detail	text	Detail message text associated with an error or warning message
21	event_hint	text	Hint message text associated with an error or warning message
22	internal_query	text	The internally-generated query text
23	internal_query_pos	int	The cursor index into the internally-generated query text
24	event_context	text	The context in which this message gets generated
25	debug_query_string	text	User-supplied query string with full detail for debugging. This string can be modified for internal use.
26	error_cursor_pos	int	The cursor index into the query string
27	func_name	text	The function in which this message is generated
28	file_name	text	The internal code file where the message originated
29	file_line	int	The line of the code file where the message originated
30	stack_trace	text	Stack trace text associated with this message

WarehousePG provides a utility called `gplogfilter` that can be used to search through a WarehousePG log file for entries matching the specified criteria. By default, this utility searches through the WarehousePG coordinator log file in the default logging location. For example, to display the last three lines of the coordinator log file:

```
$ gplogfilter -n 3
```

You can also use `gplogfilter` to search through all segment log files at once by running it through the `gpssh` utility. For example, to display the last three lines of each segment log file:

```
$ gpssh -f seg_host_file
  => source /usr/edb/whpg7/greenplum_path.sh
  => gplogfilter -n 3 /data*/*/gp*/pg_log/gpdb*.csv
```

The following are the WarehousePG security-related audit (or logging) server configuration parameters that are set in the postgresql.conf configuration file:

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Field Name	Value Range	Default	Description
log_connections	Boolean	off	This outputs a line to the server log detailing each successful connection. Some client programs, like psql, attempt to connect twice while determining if a password is required, so duplicate “connection received” messages do not always indicate a problem.
log_disconnections	Boolean	off	This outputs a line in the server log at termination of a client session, and includes the duration of the session.
log_statement	NONE DDL MOD ALL	ALL	Controls which SQL statements are logged. DDL logs all data definition commands like CREATE, ALTER, and DROP commands. MOD logs all DDL statements, plus INSERT, UPDATE, DELETE, TRUNCATE, and COPY FROM. PREPARE and EXPLAIN ANALYZE statements are also logged if their contained command is of an appropriate type.
log_hostname	Boolean	off	By default, connection log messages only show the IP address of the connecting host. Turning on this option causes logging of the host name as well. Note that depending on your host name resolution setup this might impose a non-negligible performance penalty.
log_duration	Boolean	off	Causes the duration of every completed statement which satisfies log_statement to be logged.
log_error_verbosity	TERSE DEFAULT VERBOSE	DEFAULT	Controls the amount of detail written in the server log for each message that is logged.
log_min_duration_statement	number of milliseconds, 0, -1	-1	Logs the statement and its duration on a single log line if its duration is greater than or equal to the specified number of milliseconds. Setting this to 0 will print all statements and their durations. -1 deactivates the feature. For example, if you set it to 250 then all SQL statements that run 250ms or longer will be logged. Enabling this option can be useful in tracking down unoptimized queries in your applications.
log_min_messages	DEBUG5 DEBUG4 DEBUG3 DEBUG2 DEBUG1 INFO NOTICE WARNING ERROR LOG FATAL PANIC	NOTICE	Controls which message levels are written to the server log. Each level includes all the levels that follow it. The later the level, the fewer messages are sent to the log.
log_rotation_size	0 - INT_MAX/1024 kilobytes	1048576	When greater than 0, a new log file is created when this number of kilobytes have been written to the log. Set to zero to deactivate size-based creation of new log files.
log_rotation_age	Any valid time expression (number and unit)	1d	Determines the lifetime of an individual log file. When this amount of time has elapsed since the current log file was created, a new log file will be created. Set to zero to deactivate time-based creation of new log files.
log_statement_stats	Boolean	off	For each query, write total performance statistics of the query parser, planner, and executor to the server log. This is a crude profiling instrument.
log_truncate_on_rotation	Boolean	off	Truncates (overwrites), rather than appends to, any existing log file of the same name. Truncation will occur only when a new file is being opened due to time-based rotation. For example, using this setting in combination with a log_filename such as gpseg#-%H.log would result in generating twenty-four hourly log files and then cyclically overwriting them. When off, pre-existing files will be appended to in all cases.

Parent topic: WarehousePG Security Configuration Guide

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5.6 Encrypting Data and Database Connections

This topic describes how to encrypt data at rest in the database or in transit over the network, to protect from eavesdroppers or man-in-the-middle attacks.

- Connections between clients and the coordinator database can be encrypted with SSL. This is enabled with the `ssl` server configuration parameter, which is `off` by default. Setting the `ssl` parameter to `on` allows client communications with the coordinator to be encrypted. The coordinator database must be set up for SSL. See OpenSSL Configuration for more about encrypting client connections with SSL.
- WarehousePG allows SSL encryption of data in transit between the WarehousePG parallel file distribution server, `gpfdist` , and segment hosts. See Encrypting gpfdist Connections for more information.
- The `pgcrypto` module of encryption/decryption functions protects data at rest in the database. Encryption at the column level protects sensitive information, such as social security numbers or credit card numbers. See Encrypting Data at Rest with pgcrypto for more information.

Parent topic: WarehousePG Security Configuration Guide

Encrypting gpfdist Connections

The `gpfdists` protocol is a secure version of the `gpfdist` protocol that securely identifies the file server and the WarehousePG and encrypts the communications between them. Using `gpfdists` protects against eavesdropping and man-in-the-middle attacks.

The `gpfdists` protocol implements client/server SSL security with the following notable features:

- Client certificates are required.
- Multilingual certificates are not supported.
- A Certificate Revocation List (CRL) is not supported.
- A minimum TLS version of 1.2 is required.
- SSL renegotiation is supported.
- The SSL ignore host mismatch parameter is set to false.
- Private keys containing a passphrase are not supported for the `gpfdist` file server (server.key) or for the WarehousePG (client.key).
- It is the user's responsibility to issue certificates that are appropriate for the operating system in use. Generally, converting certificates to the required format is supported, for example using the SSL Converter at https://www.sslshopper.com/ssl-converter.html.

A `gpfdist` server started with the `--ssl` option can only communicate with the `gpfdists` protocol. A `gpfdist` server started without the `--ssl` option can only communicate with the `gpfdist` protocol. For more detail about `gpfdist` refer to the *WarehousePG Administrator Guide*.

There are two ways to enable the `gpfdists` protocol:

- Run `gpfdist` with the `--ssl` option and then use the `gpfdists` protocol in the `LOCATION` clause of a `CREATE EXTERNAL TABLE` statement.
- Use a YAML control file with the SSL option set to true and run `gpload` . Running `gpload` starts the `gpfdist` server with the `--ssl` option and then uses the `gpfdists` protocol.

When using gpfdists, the following client certificates must be located in the `$PGDATA/gpfdists` directory on each segment:

- The client certificate file, `client.crt`
- The client private key file, `client.key`
- The trusted certificate authorities, `root.crt`

> **Important** Do not protect the private key with a passphrase. The server does not prompt for a passphrase for the private key, and loading data fails with an error if one is required.

When using `gpload` with SSL you specify the location of the server certificates in the YAML control file. When using `gpfdist` with SSL, you specify the location of the server certificates with the --ssl option.

The following example shows how to securely load data into an external table. The example creates a readable external table named `ext_expenses` from all files with the `txt` extension, using the `gpfdists` protocol. The files are formatted with a pipe (`|`) as the column delimiter and an empty space as null.

1. Run `gpfdist` with the `--ssl` option on the segment hosts.
2. Log into the database and run the following command:

```
=# CREATE EXTERNAL TABLE ext_expenses
   ( name text, date date, amount float4, category text, desc1 text )
LOCATION ('gpfdists://etlhost-1:8081/*.txt', 'gpfdists://etlhost-2:8082/*.txt')
FORMAT 'TEXT' ( DELIMITER '|' NULL ' ') ;
```

Encrypting Data at Rest with pgcrypto

The pgcrypto module for WarehousePG provides functions for encrypting data at rest in the database. Administrators can encrypt columns with sensitive information, such as social security numbers or credit card numbers, to provide an extra layer of protection. Database data stored in encrypted form cannot be read by users who do not have the encryption key, and the data cannot be read directly from disk.

pgcrypto is installed by default when you install WarehousePG. You must explicitly enable pgcrypto in each database in which you want to use the module.

pgcrypto allows PGP encryption using symmetric and asymmetric encryption. Symmetric encryption encrypts and decrypts data using the same key and is faster than asymmetric encryption. It is the preferred method in an environment where exchanging secret keys is not an issue. With asymmetric encryption, a public key is used to encrypt data and a private key is used to decrypt data. This is slower then symmetric encryption and it requires a stronger key.

Using pgcrypto always comes at the cost of performance and maintainability. It is important to use encryption only with the data that requires it. Also, keep in mind that you cannot search encrypted data by indexing the data.

Before you implement in-database encryption, consider the following PGP limitations.

- No support for signing. That also means that it is not checked whether the encryption sub-key belongs to the coordinator key.
- No support for encryption key as coordinator key. This practice is generally discouraged, so this limitation should not be a problem.
- No support for several subkeys. This may seem like a problem, as this is common practice. On the other hand, you should not use your regular GPG/PGP keys with pgcrypto, but create new ones, as the usage scenario is rather different.

WarehousePG is compiled with zlib by default; this allows PGP encryption functions to compress data before encrypting. When compiled with OpenSSL, more algorithms will be available.

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Because pgcrypto functions run inside the database server, the data and passwords move between pgcrypto and the client application in clear-text. For optimal security, you should connect locally or use SSL connections and you should trust both the system and database administrators.

pgcrypto configures itself according to the findings of the main PostgreSQL configure script.

When compiled with `zlib`, pgcrypto encryption functions are able to compress data before encrypting.

Pgcrypto has various levels of encryption ranging from basic to advanced built-in functions. The following table shows the supported encryption algorithms.

Value Functionality	Built-in	With OpenSSL
MD5	yes	yes
SHA1	yes	yes
SHA224/256/384/512	yes	yes [^1]
Other digest algorithms	no	yes [^2]
Blowfish	yes	yes
AES	yes	yes [^3]
DES/3DES/CAST5	no	yes
Raw Encryption	yes	yes
PGP Symmetric-Key	yes	yes
PGP Public Key	yes	yes

Creating PGP Keys

To use PGP asymmetric encryption in WarehousePG, you must first create public and private keys and install them.

This section assumes you are installing WarehousePG on a Linux machine with the Gnu Privacy Guard (`gpg`) command line tool. Use the latest version of GPG to create keys. Download and install Gnu Privacy Guard (GPG) for your operating system from https://www.gnupg.org/download/. On the GnuPG website you will find installers for popular Linux distributions and links for Windows and Mac OS X installers.

1. As root, run the following command and choose option 1 from the menu:

```
# gpg --gen-key
gpg (GnuPG) 2.0.14; Copyright (C) 2009 Free Software Foundation, Inc.
This is free software: you are free to change and redistribute it.
There is NO WARRANTY, to the extent permitted by law.

gpg: directory '/root/.gnupg' created
gpg: new configuration file '/root/.gnupg/gpg.conf' created
gpg: WARNING: options in '/root/.gnupg/gpg.conf' are not yet active during this run
gpg: keyring '/root/.gnupg/secring.gpg' created
gpg: keyring '/root/.gnupg/pubring.gpg' created
Please select what kind of key you want:
  (1) RSA and RSA (default)
  (2) DSA and Elgamal
  (3) DSA (sign only)
  (4) RSA (sign only)
Your selection? **1**
```

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2. Respond to the prompts and follow the instructions, as shown in this example:

```
RSA keys may be between 1024 and 4096 bits long.
What keysize do you want? (2048) Press enter to accept default key size
Requested keysize is 2048 bits
Please specify how long the key should be valid.
 0 = key does not expire
 <n> = key expires in n days
 <n>w = key expires in n weeks
 <n>m = key expires in n months
 <n>y = key expires in n years
 Key is valid for? (0) **365**
Key expires at Wed 13 Jan 2016 10:35:39 AM PST
Is this correct? (y/N) **y**

GnuPG needs to construct a user ID to identify your key.

Real name: **John Doe**
Email address: **jdoe@email.com**
Comment:
You selected this USER-ID:
 "John Doe <jdoe@email.com>"

Change (N)ame, (C)omment, (E)mail or (O)kay/(Q)uit? **O**
You need a Passphrase to protect your secret key.
*\(For this demo the passphrase is blank.\)*
can't connect to '/root/.gnupg/S.gpg-agent': No such file or directory
You don't want a passphrase - this is probably a *bad* idea!
I will do it anyway.  You can change your passphrase at any time,
using this program with the option "--edit-key".

We need to generate a lot of random bytes. It is a good idea to perform
some other action (type on the keyboard, move the mouse, utilize the
disks) during the prime generation; this gives the random number
generator a better chance to gain enough entropy.
We need to generate a lot of random bytes. It is a good idea to perform
some other action (type on the keyboard, move the mouse, utilize the
disks) during the prime generation; this gives the random number
generator a better chance to gain enough entropy.
gpg: /root/.gnupg/trustdb.gpg: trustdb created
gpg: key 2027CC30 marked as ultimately trusted
public and secret key created and signed.

gpg:  checking the trustdbgpg:
      3 marginal(s) needed, 1 complete(s) needed, PGP trust model
gpg:  depth: 0  valid1  signed0  trust: 0-, 0q, 0n, 0m, 0f, 1u
gpg:  next trustdb check due at 2016-01-13
pub   2048R/2027CC30 2015-01-13 [expires: 2016-01-13]
      Key fingerprint = 7EDA 6AD0 F5E0 400F 4D45   3259 077D 725E 2027 CC30
uid                  John Doe <jdoe@email.com>
sub   2048R/4FD2EFBB 2015-01-13 [expires: 2016-01-13]
```

3. List the PGP keys by entering the following command:

```
gpg --list-secret-keys
/root/.gnupg/secring.gpg
------------------------
sec   2048R/2027CC30 2015-01-13 [expires: 2016-01-13]
uid                  John Doe <jdoe@email.com>
ssb   2048R/4FD2EFBB 2015-01-13
```

2027CC30 is the public key and will be used to *encrypt* data in the database. 4FD2EFBB is the private (secret) key and will be used to *decrypt* data.

4. Export the keys using the following commands:

```
# gpg -a --export 4FD2EFBB > public.key
# gpg -a --export-secret-keys 2027CC30 > secret.key
```

See the pgcrypto documentation for more information about PGP encryption functions.

Encrypting Data in Tables using PGP

This section shows how to encrypt data inserted into a column using the PGP keys you generated.

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1. Dump the contents of the `public.key` file and then copy it to the clipboard:

```
# cat public.key
-----BEGIN PGP PUBLIC KEY BLOCK-----
Version: GnuPG v2.0.14 (GNU/Linux)

mQENBFS1Zf0BCADNw8Qvk1V1C36Kfcwd3Kpm/dijPfRyyEwB6PqKyA05jtWiXZTh
2His1ojSP6LI0cSkIqMU9LAlncecZhRIhBhuVgKlGSgd9texg2nnSL9Admqik/yX
R5syVKG+qcdWuvyZg9oOOmeyjhc3n+kkbRTEMuM3flbMs8shOwzMvstCUVmuHU/V
vG5rJAe8PuYDSJCJ74I6w7SOH3RiRIc7IfL6xYddV42l3ctd44bl8/i71hq2UyN2
/Hbsjii2ymg7ttw3jsWAx2gP9nssDgoy8QDy/o9nNqC8EGlig96ZFnFnE6Pwbhn+
ic8MD0lK5/GAlR6Hc0ZIHf8KEcavruQlikjnABEBAAG0HHRlc3Qga2V5IDx0ZXN0
a2V5QGVtYWlsLmNvbT6JAT4EEwECACgFAlS1Zf0CGwMFCQHhM4AGCwkIBwMCBhUI
AgkKCwQWAgMBAh4BAheAAAoJEAd9cl4gJ8wwbfwH/3VyVsPkQl1owRJNxvXGt1bY
7BfrvU52yk+PPZYoes9UpdL3CMRk8gAM9bx5Sk08q2UXSZLC6fFOpEW4uWgmGYf8
JRoC3ooezTkmCBW8I1bU0qGetzVxopdXLuPGCE7hVWQe9HcSntiTLxGov1mJAwO7
TAoccXLbyuZh9Rf5vLoQdKzcCyOHh5IqXaQOT100TeFeEpb9TIiwcntg3WCSU5P0
DGoUAOanjDZ3KE8Qp7V74fhG1EZVzHb8FajR62CXSHFKqpBgiNxnTOk45NbXADn4
eTUXPSnwPi46qoAp9UQogsfGyB1XDOTB2UOqhutAMECaM7VtpePv79i0Z/NfnBe5
AQ0EVLVl/QEIANabFdQ+8QMCADOipM1bF/JrQt3zUoc4BTqICaxdyzAfz0tUSf/7
Zro2us99GlARqLWd8EqJcl/xmfcJiZyUam6ZAzzFXCgnH5Y1sdtMTJZdLp5WeOjw
gCWG/ZLu4wzxOFFzDkiPv9RDw6e5MNLtJrSp4hS5o2apKdbO4Ex83O4mJYnav/rE
iDDCWU4T0lhv3hSKCpke6LcwsX+7liozp+aNmP0Ypwfi4hR3UUMP70+V1beFqW2J
bVLz3lLLouHRgpCzla+PzzbEKs16jq77vG9kqZTCIzXoWaLljuitRlfJkO3vQ9hO
v/8yAnkcAmowZrIBlyFg2KBzhunYmN2YvkUAEQEAAYkBJQQYAQIADwUCVLVl/QIb
DAUJAeEzgAAKCRAHfXJeICfMMOHYCACFhInZA9uAM3TC44l+MrgMUJ3rW9izrO48
WrdTsxR8WkSNbIxJoWnYxYuLyPb/shc9k65huw2SSDkj//0fRrI61FPHQNPSvz62
WH+N2lasoUaoJjb2kQGhLOnFbJuevkyBylRz+hI/+8rJKcZOjQkmmK8Hkk8qb5x/
HMUc55H0g2qQAY0BpnJHgOOQ45Q6pk3G2/7Dbek5WJ6K1wUrFy51sNlGWE8pvgEx
/UUZB+dYqCwtvX0nnBu1KNCmk2AkEcFK3YoliCxomdOxhFOv9AKjjojDyC65KJci
Pv2MikPS2fKOAg1R3LpMa8zDEtl4w3vckPQNrQNnYuUtfj6ZoCxv
=XZ8J
-----END PGP PUBLIC KEY BLOCK-----
```

2. Create a table called `userssn` and insert some sensitive data, social security numbers for Bob and Alice, in this example. Paste the public.key contents after "dearmor(".

```
CREATE TABLE userssn( ssn_id SERIAL PRIMARY KEY,
    username varchar(100), ssn bytea);

INSERT INTO userssn(username, ssn)
SELECT robotccs.username, pgp_pub_encrypt(robotccs.ssn, keys.pubkey) AS ssn
FROM (
        VALUES ('Alice', '123-45-6788'), ('Bob', '123-45-6799'))
            AS robotccs(username, ssn)
CROSS JOIN  (SELECT  dearmor('-----BEGIN PGP PUBLIC KEY BLOCK-----
Version: GnuPG v2.0.14 (GNU/Linux)

mQENBFS1Zf0BCADNw8Qvk1V1C36Kfcwd3Kpm/dijPfRyyEwB6PqKyA05jtWiXZTh
2His1ojSP6LI0cSkIqMU9LAlncecZhRIhBhuVgKlGSgd9texg2nnSL9Admqik/yX
R5syVKG+qcdWuvyZg9oOOmeyjhc3n+kkbRTEMuM3flbMs8shOwzMvstCUVmuHU/V
vG5rJAe8PuYDSJCJ74I6w7SOH3RiRIc7IfL6xYddV42l3ctd44bl8/i71hq2UyN2
/Hbsjii2ymg7ttw3jsWAx2gP9nssDgoy8QDy/o9nNqC8EGlig96ZFnFnE6Pwbhn+
ic8MD0lK5/GAlR6Hc0ZIHf8KEcavruQlikjnABEBAAG0HHRlc3Qga2V5IDx0ZXN0
a2V5QGVtYWlsLmNvbT6JAT4EEwECACgFAlS1Zf0CGwMFCQHhM4AGCwkIBwMCBhUI
AgkKCwQWAgMBAh4BAheAAAoJEAd9cl4gJ8wwbfwH/3VyVsPkQl1owRJNxvXGt1bY
7BfrvU52yk+PPZYoes9UpdL3CMRk8gAM9bx5Sk08q2UXSZLC6fFOpEW4uWgmGYf8
JRoC3ooezTkmCBW8I1bU0qGetzVxopdXLuPGCE7hVWQe9HcSntiTLxGov1mJAwO7
TAoccXLbyuZh9Rf5vLoQdKzcCyOHh5IqXaQOT100TeFeEpb9TIiwcntg3WCSU5P0
DGoUAOanjDZ3KE8Qp7V74fhG1EZVzHb8FajR62CXSHFKqpBgiNxnTOk45NbXADn4
eTUXPSnwPi46qoAp9UQogsfGyB1XDOTB2UOqhutAMECaM7VtpePv79i0Z/NfnBe5
AQ0EVLVl/QEIANabFdQ+8QMCADOipM1bF/JrQt3zUoc4BTqICaxdyzAfz0tUSf/7
Zro2us99GlARqLWd8EqJcl/xmfcJiZyUam6ZAzzFXCgnH5Y1sdtMTJZdLp5WeOjw
gCWG/ZLu4wzxOFFzDkiPv9RDw6e5MNLtJrSp4hS5o2apKdbO4Ex83O4mJYnav/rE
iDDCWU4T0lhv3hSKCpke6LcwsX+7liozp+aNmP0Ypwfi4hR3UUMP70+V1beFqW2J
bVLz3lLLouHRgpCzla+PzzbEKs16jq77vG9kqZTCIzXoWaLljuitRlfJkO3vQ9hO
v/8yAnkcAmowZrIBlyFg2KBzhunYmN2YvkUAEQEAAYkBJQQYAQIADwUCVLVl/QIb
DAUJAeEzgAAKCRAHfXJeICfMMOHYCACFhInZA9uAM3TC44l+MrgMUJ3rW9izrO48
WrdTsxR8WkSNbIxJoWnYxYuLyPb/shc9k65huw2SSDkj//0fRrI61FPHQNPSvz62
WH+N2lasoUaoJjb2kQGhLOnFbJuevkyBylRz+hI/+8rJKcZOjQkmmK8Hkk8qb5x/
HMUc55H0g2qQAY0BpnJHgOOQ45Q6pk3G2/7Dbek5WJ6K1wUrFy51sNlGWE8pvgEx
/UUZB+dYqCwtvX0nnBu1KNCmk2AkEcFK3YoliCxomdOxhFOv9AKjjojDyC65KJci
Pv2MikPS2fKOAg1R3LpMa8zDEtl4w3vckPQNrQNnYuUtfj6ZoCxv
=XZ8J
-----END PGP PUBLIC KEY BLOCK-----' AS pubkey) AS keys;
```

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3. Verify that the `ssn` column is encrypted.

```
test_db=# select * from userssn;
ssn_id   | 1
username | Alice
ssn      | \301\300L\003\235M%_O\322\357\273\001\010\000\272\227\010\341\216\360\217C\020\261)_\367
[\227\034\313:C\354d<\337\006Q\351('\2330\031lX\263Qf\341\262\200\3015\235\036AK\242fL+\315g\322
7u\270*\304\361\355\220\021\330"\200%\264\274}R\213\377\363\235\366\030\023)\364!\331\303\237t\277=
f \015\004\242\231\263\225%\032\271a\001\035\277\021\375X\232\304\305/\340\334\0131\325\344[~\362\0
37-\251\336\303\340\377_\011\275\301/MY\334\343\245\244\372y\257S\374\230\346\277\373W\346\230\276\
017fi\226Q\307\012\326\3646\000\326\005:E\364W\252=zz\010(:\343Y\237\257iqU\0326\350=v0\362\327\350\
315G^\027:K_9\254\362\354\215<\001\304\357\331\355\323,\302\213Fe\265\315\232\367\254\245%(\\\373
4\254\230\331\356\006B\257\333\326H\022\013\353\216F?\023\220\370\035vH5/\227\344b\322\227\026\362=\
42\033\322<\001}\243\224;)\030zqX\214\340\221\035\275U\345\327\214\032\351\223c\2442\345\304K\016\
011\214\307\227\237\270\026'R\205\205a~1\263\236[\037C\260\031\205\374\245\317\033k|\366\253\037
---------+--------------------------------------------------------------------------------------------
--------------------------------------------------------------------------------------------------
--------------------------------------------------------------------------------------------------
--------------------------------------------------------------------------------------------------
--------------------------------------------------------------------------------------------------
--------------------------------------------------------------------------------------------------
--------------------------------------------------------------------------------------------------
--------------------------------------------------------------------------------------------------
--------------------------------------------------------------------------------------------------
--------------------------------------------------------------------------
ssn_id   | 2
username | Bob
ssn      | \301\300L\003\235M%_O\322\357\273\001\007\377t>\345\343,\200\256\272\300\012\033M4\265\032L
L[v\262k\244\2435\264\232B\357\370d9\375\011\002\327\235<\246\210b\030\012\337@\226Z\361\246\032\00
7'\012c\353]\355d7\360T\335\314\367\370;X\371\350*\231\212\260B\010#RQ0\223\253c7\0132b\355\242\233\34
1\000\370\370\366\013\022\357\005i\202~\005\\z\301o\012\230Z\014\362\244\324&\243g\351\362\325\375
\213\032\226$\2751\256XR\346k\266\030\234\267\201vUh\004\250\337A\231\223u\247\366/i\022\275\276\350\2
20\316\306|\203+\010\261;\232\254tp\255\243\261\373Rq;\316w\357\006\207\374U\333\365\365\245hg\031\005
\322\347ea\220\015l\212g\337\264\336b\263\004\311\210.4\340G+\221\274D\035\375\2216\241'\346a0\273wE\2
12\342y^\202\262|A7\202t\240\333p\345G\373\253\243oCO\011\360\247\211\014\024{\272\271\322<\001\267
\347\240\005\213\0078\036\210\307$\317\322\311\222\035\354\006<\266\264\004\376\251q\256\220(+\030\
3270\013c\327\272\212%\363\033\252\322\337\354\276\225\232\201\212^\304\210\2269@\3230\370{
```

4. Extract the public.key ID from the database:

```
SELECT pgp_key_id(dearmor('-----BEGIN PGP PUBLIC KEY BLOCK-----
Version: GnuPG v2.0.14 (GNU/Linux)

mQENBFS1Zf0BCADNw8Qvk1V1C36Kfcwd3Kpm/dijPfRyyEwB6PqKyA05jtWiXZTh
2His1ojSP6LI0cSkIqMU9LAlncecZhRIhBhuVgKlGSgd9texg2nnSL9Admqik/yX
R5syVKG+qcdWuvyZg9oOOmeyjhc3n+kkbRTEMuM3flbMs8shOwzMvstCUVmuHU/V
vG5rJAe8PuYDSJCJ74I6w7SOH3RiRIc7IfL6xYddV42l3ctd44bl8/i71hq2UyN2
/Hbsjii2ymg7ttw3jsWAx2gP9nssDgoy8QDy/o9nNqC8EGlig96ZFnFnE6Pwbhn+
ic8MD0lK5/GAlR6Hc0ZIHf8KEcavruQlikjnABEBAAG0HHRlc3Qga2V5IDx0ZXN0
a2V5QGVtYWlsLmNvbT6JAT4EEwECACgFAlS1Zf0CGwMFCQHhM4AGCwkIBwMCBhUI
AgkKCwQWAgMBAh4BAheAAAoJEAd9cl4gJ8wwbfwH/3VyVsPkQl1owRJNxvXGt1bY
7BfrvU52yk+PPZYoes9UpdL3CMRk8gAM9bx5Sk08q2UXSZLC6fFOpEW4uWgmGYf8
JRoC3ooezTkmCBW8I1bU0qGetzVxopdXLuPGCE7hVWQe9HcSntiTLxGov1mJAwO7
TAoccXLbyuZh9Rf5vLoQdKzcCyOHh5IqXaQOT100TeFeEpb9TIiwcntg3WCSU5P0
DGoUAOanjDZ3KE8Qp7V74fhG1EZVzHb8FajR62CXSHFKqpBgiNxnTOk45NbXADn4
eTUXPSnwPi46qoAp9UQogsfGyB1XDOTB2UOqhutAMECaM7VtpePv79i0Z/NfnBe5
AQ0EVLVl/QEIANabFdQ+8QMCADOipM1bF/JrQt3zUoc4BTqICaxdyzAfz0tUSf/7
Zro2us99GlARqLWd8EqJcl/xmfcJiZyUam6ZAzzFXCgnH5Y1sdtMTJZdLp5WeOjw
gCWG/ZLu4wzxOFFzDkiPv9RDw6e5MNLtJrSp4hS5o2apKdbO4Ex83O4mJYnav/rE
iDDCWU4T0lhv3hSKCpke6LcwsX+7liozp+aNmP0Ypwfi4hR3UUMP70+V1beFqW2J
bVLz3lLLouHRgpCzla+PzzbEKs16jq77vG9kqZTCIzXoWaLljuitRlfJkO3vQ9hO
v/8yAnkcAmowZrIBlyFg2KBzhunYmN2YvkUAEQEAAYkBJQQYAQIADwUCVLVl/QIb
DAUJAeEzgAAKCRAHfXJeICfMMOHYCACFhInZA9uAM3TC44l+MrgMUJ3rW9izrO48
WrdTsxR8WkSNbIxJoWnYxYuLyPb/shc9k65huw2SSDkj//0fRrI61FPHQNPSvz62
WH+N2lasoUaoJjb2kQGhLOnFbJuevkyBylRz+hI/+8rJKcZOjQkmmK8Hkk8qb5x/
HMUc55H0g2qQAY0BpnJHgOOQ45Q6pk3G2/7Dbek5WJ6K1wUrFy51sNlGWE8pvgEx
/UUZB+dYqCwtvX0nnBu1KNCmk2AkEcFK3YoliCxomdOxhFOv9AKjjojDyC65KJci
Pv2MikPS2fKOAg1R3LpMa8zDEtl4w3vckPQNrQNnYuUtfj6ZoCxv
=XZ8J
-----END PGP PUBLIC KEY BLOCK-----'));

pgp_key_id | 9D4D255F4FD2EFBB
```

This shows that the PGP key ID used to encrypt the `ssn` column is 9D4D255F4FD2EFBB. It is recommended to perform this step whenever a new key is created and then store the ID for tracking.

You can use this key to see which key pair was used to encrypt the data:

```
SELECT username, pgp_key_id(ssn) As key_used
FROM userssn;
username | Bob
key_used | 9D4D255F4FD2EFBB
---------+-----------------
username | Alice
key_used | 9D4D255F4FD2EFBB
```

> **Note** Different keys may have the same ID. This is rare, but is a normal event. The client application should try to decrypt with each one to see which fits — like handling `ANYKEY`. See pgp_key_id() in the pgcrypto documentation.

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5. Decrypt the data using the private key.

```
SELECT username, pgp_pub_decrypt(ssn, keys.privkey)
                AS decrypted_ssn FROM userssn
                CROSS JOIN
                (SELECT dearmor('-----BEGIN PGP PRIVATE KEY BLOCK-----
Version: GnuPG v2.0.14 (GNU/Linux)

lQOYBFS1Zf0BCADNw8Qvk1V1C36Kfcwd3Kpm/dijPfRyyEwB6PqKyA05jtWiXZTh
2His1ojSP6LI0cSkIqMU9LAlncecZhRIhBhuVgKlGSgd9texg2nnSL9Admqik/yX
R5syVKG+qcdWuvyZg9oOOmeyjhc3n+kkbRTEMuM3flbMs8shOwzMvstCUVmuHU/V
vG5rJAe8PuYDSJCJ74I6w7SOH3RiRIc7IfL6xYddV42l3ctd44bl8/i71hq2UyN2
/Hbsjii2ymg7ttw3jsWAx2gP9nssDgoy8QDy/o9nNqC8EGlig96ZFnFnE6Pwbhn+
ic8MD0lK5/GAlR6Hc0ZIHf8KEcavruQlikjnABEBAAEAB/wNfjjvP1brRfjjIm/j
XwUNm+sI4v2Ur7qZC94VTukPGf67lvqcYZJuqXxvZrZ8bl6mvl65xEUiZYy7BNA8
fe0PaM4Wy+Xr94Cz2bPbWgawnRNN3GAQy4rlBTrvqQWy+kmpbd87iTjwZidZNNmx
02iSzraq41Rt0Zx21Jh4rkpF67ftmzOH0vlrS0bWOvHUeMY7tCwmdPe9HbQeDlPr
n9CllUqBn4/acTtCClWAjREZn0zXAsNixtTIPC1V+9nO9YmecMkVwNfIPkIhymAM
OPFnuZ/Dz1rCRHjNHb5j6ZyUM5zDqUVnnezktxqrOENSxm0gfMGcpxHQogUMzb7c
6UyBBADSCXHPfo/VPVtMm5p1yGrNOR2jR2rUj9+poZzD2gjkt5G/xIKRlkB4uoQl
emu27wr9dVEX7ms0nvDq58iutbQ4d0JIDlcHMeSRQZluErblB75Vj3HtImblPjpn
4Jx6SWRXPUJPGXGI87u0UoBH0Lwij7M2PW7l1ao+MLEA9jAjQwQA+sr9BKPL4Ya2
r5nE72gsbCCLowkC0rdldf1RGtobwYDMpmYZhOaRKjkOTMG6rCXJxrf6LqiN8w/L
/gNziTmch35MCq/MZzA/bN4VMPyeIlwzxVZkJLsQ7yyqX/A7ac7B7DH0KfXciEXW
MSOAJhMmklW1Q1RRNw3cnYi8w3q7X40EAL/w54FVvvPqp3+sCd86SAAapM4UO2R3
tIsuNVemMWdgNXwvK8AJsz7VreVU5yZ4B8hvCuQj1C7geaN/LXhiT8foRsJC5o71
Bf+iHC/VNEv4k4uDb4lOgnHJYYyifB1wC+nn/EnXCZYQINMia1a4M6Vqc/RIfTH4
nwkZt/89LsAiR/20HHRlc3Qga2V5IDx0ZXN0a2V5QGVtYWlsLmNvbT6JAT4EEwEC
ACgFAlS1Zf0CGwMFCQHhM4AGCwkIBwMCBhUIAgkKCwQWAgMBAh4BAheAAAoJEAd9
cl4gJ8wwbfwH/3VyVsPkQl1owRJNxvXGt1bY7BfrvU52yk+PPZYoes9UpdL3CMRk
8gAM9bx5Sk08q2UXSZLC6fFOpEW4uWgmGYf8JRoC3ooezTkmCBW8I1bU0qGetzVx
opdXLuPGCE7hVWQe9HcSntiTLxGov1mJAwO7TAoccXLbyuZh9Rf5vLoQdKzcCyOH
h5IqXaQOT100TeFeEpb9TIiwcntg3WCSU5P0DGoUAOanjDZ3KE8Qp7V74fhG1EZV
zHb8FajR62CXSHFKqpBgiNxnTOk45NbXADn4eTUXPSnwPi46qoAp9UQogsfGyB1X
DOTB2UOqhutAMECaM7VtpePv79i0Z/NfnBedA5gEVLVl/QEIANabFdQ+8QMCADOi
pM1bF/JrQt3zUoc4BTqICaxdyzAfz0tUSf/7Zro2us99GlARqLWd8EqJcl/xmfcJ
iZyUam6ZAzzFXCgnH5Y1sdtMTJZdLp5WeOjwgCWG/ZLu4wzxOFFzDkiPv9RDw6e5
MNLtJrSp4hS5o2apKdbO4Ex83O4mJYnav/rEiDDCWU4T0lhv3hSKCpke6LcwsX+7
liozp+aNmP0Ypwfi4hR3UUMP70+V1beFqW2JbVLz3lLLouHRgpCzla+PzzbEKs16
jq77vG9kqZTCIzXoWaLljuitRlfJkO3vQ9hOv/8yAnkcAmowZrIBlyFg2KBzhunY
mN2YvkUAEQEAAQAH/A7r4hDrnmzX3QU6FAzePlRB7niJtE2IEN8AufF05Q2PzKU/
c1S72WjtqMAIAgYasDkOhfhcxanTneGuFVYggKT3eSDm1RFKpRjX22m0zKdwy67B
Mu95V2Oklul6OCm8dO6+2fmkGxGqc4ZsKy+jQxtxK3HG9YxMC0dvA2v2C5N4TWi3
Utc7zh//k6IbmaLd7F1d7DXt7Hn2Qsmo8I1rtgPE8grDToomTnRUodToyejEqKyI
ORwsp8n8g2CSFaXSrEyU6HbFYXSxZealhQJGYLFOZdR0MzVtZQCn/7n+IHjupndC
Nd2a8DVx3yQS3dAmvLzhFacZdjXi31wvj0moFOkEAOCz1E63SKNNksniQ11lRMJp
gaov6Ux/zGLMstwTzNouI+Kr8/db0GlSAy1Z3UoAB4tFQXEApoX9A4AJ2KqQjqOX
cZVULenfDZaxrbb9Lid7ZnTDXKVyGTWDF7ZHavHJ4981mCW17lU11zHBB9xMlx6p
dhFvb0gdy0jSLaFMFr/JBAD0fz3RrhP7e6Xll2zdBqGthjC5S/IoKwwBgw6ri2yx
LoxqBr2pl9PotJJ/JUMPhD/LxuTcOZtYjy8PKgm5jhnBDq3Ss0kNKAY1f5EkZG9a
6I4iAX/NekqSyF+OgBfC9aCgS5RG8hYoOCbp8na5R3bgiuS8IzmVmm5OhZ4MDEwg
nQP7BzmR0p5BahpZ8r3Ada7FcK+0ZLLRdLmOYF/yUrZ53SoYCZRzU/GmtQ7LkXBh
Gjqied9Bs1MHdNUolq7GaexcjZmOWHEf6w9+9M4+vxtQq1nkIWqtaphewEmd5/nf
EP3sIY0EAE3mmiLmHLqBju+UJKMNwFNeyMTqgcg50ISH8J9FRIkBJQQYAQIADwUC
VLVl/QIbDAUJAeEzgAAKCRAHfXJeICfMMOHYCACFhInZA9uAM3TC44l+MrgMUJ3r
W9izrO48WrdTsxR8WkSNbIxJoWnYxYuLyPb/shc9k65huw2SSDkj//0fRrI61FPH
QNPSvz62WH+N2lasoUaoJjb2kQGhLOnFbJuevkyBylRz+hI/+8rJKcZOjQkmmK8H
kk8qb5x/HMUc55H0g2qQAY0BpnJHgOOQ45Q6pk3G2/7Dbek5WJ6K1wUrFy51sNlG
WE8pvgEx/UUZB+dYqCwtvX0nnBu1KNCmk2AkEcFK3YoliCxomdOxhFOv9AKjjojD
yC65KJciPv2MikPS2fKOAg1R3LpMa8zDEtl4w3vckPQNrQNnYuUtfj6ZoCxv
=fa+6
-----END PGP PRIVATE KEY BLOCK-----') AS privkey) AS keys;

username | decrypted_ssn
----------+---------------
 Alice    | 123-45-6788
 Bob      | 123-45-6799
(2 rows)
```

If you created a key with passphrase, you may have to enter it here. However for the purpose of this example, the passphrase is blank.

Key Management

Whether you are using symmetric (single private key) or asymmetric (public and private key) cryptography, it is important to store the coordinator or private key securely. There are many options for storing encryption keys, for example, on a file system, key vault, encrypted USB, trusted platform module (TPM), or hardware security module (HSM).

Consider the following questions when planning for key management:

- Where will the keys be stored?
- When should keys expire?
- How are keys protected?
- How are keys accessed?
- How can keys be recovered and revoked?

The Open Web Application Security Project (OWASP) provides a very comprehensive guide to securing encryption keys.

[^1]: SHA2 algorithms were added to OpenSSL in version 0.9.8. For older versions, pgcrypto will use built-in code.

[^2]: Any digest algorithm OpenSSL supports is automatically picked up. This is not possible with ciphers, which need to be supported explicitly.

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[^3]: AES is included in OpenSSL since version 0.9.7. For older versions, pgcrypto will use built-in code.

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5.7 Security Best Practices

Describes basic security best practices that you should follow to ensure the highest level of system security.

In the default WarehousePG security configuration:

- Only local connections are allowed.
- Basic authentication is configured for the superuser (`gpadmin`).
- The superuser is authorized to do anything.
- Only database role passwords are encrypted.

System User (gpadmin)

Secure and limit access to the `gpadmin` system user.

WarehousePG requires a UNIX user id to install and initialize the WarehousePG cluster. This system user is referred to as `gpadmin` in the WarehousePG documentation. The `gpadmin` user is the default database superuser in WarehousePG, as well as the file system owner of the WarehousePG installation and its underlying data files. The default administrator account is fundamental to the design of WarehousePG. The system cannot run without it, and there is no way to limit the access of the `gpadmin` user id.

The `gpadmin` user can bypass all security features of WarehousePG. Anyone who logs on to a WarehousePG host with this user id can read, alter, or delete any data, including system catalog data and database access rights. Therefore, it is very important to secure the `gpadmin` user id and only allow essential system administrators access to it.

Administrators should only log in to WarehousePG as `gpadmin` when performing certain system maintenance tasks (such as upgrade or expansion).

Database users should never log on as `gpadmin` , and ETL or production workloads should never run as `gpadmin` .

Superusers

Roles granted the `SUPERUSER` attribute are superusers. Superusers bypass all access privilege checks and resource queues. Only system administrators should be given superuser rights.

See "Altering Role Attributes" in the *WarehousePG Administrator Guide*.

Login Users

Assign a distinct role to each user who logs in and set the `LOGIN` attribute.

For logging and auditing purposes, each user who is allowed to log in to WarehousePG should be given their own database role. For applications or web services, consider creating a distinct role for each application or service. See "Creating New Roles (Users)" in the *WarehousePG Administrator Guide*.

Each login role should be assigned to a single, non-default resource queue.

Groups

Use groups to manage access privileges.

Create a group for each logical grouping of object/access permissions.

Every login user should belong to one or more roles. Use the `GRANT` statement to add group access to a role. Use the `REVOKE` statement to remove group access from a role.

The `LOGIN` attribute should not be set for group roles.

See "Creating Groups (Role Membership)" in the *WarehousePG Administrator Guide*.

Object Privileges

Only the owner and superusers have full permissions to new objects. Permission must be granted to allow other rules (users or groups) to access objects. Each type of database object has different privileges that may be granted. Use the `GRANT` statement to add a permission to a role and the `REVOKE` statement to remove the permission.

You can change the owner of an object using the `REASSIGN OWNED BY` statement. For example, to prepare to drop a role, change the owner of the objects that belong to the role. Use the `DROP OWNED BY` to drop objects, including dependent objects, that are owned by a role.

Schemas can be used to enforce an additional layer of object permissions checking, but schema permissions do not override object privileges set on objects contained within the schema.

Operating System Users and File System

> **Note** Commands shown in this section should be run as the root user.

To protect the network from intrusion, system administrators should verify the passwords used within an organization are sufficiently strong. The following recommendations can strengthen a password:

- Minimum password length recommendation: At least 9 characters. MD5 passwords should be 15 characters or longer.
- Mix upper and lower case letters.
- Mix letters and numbers.
- Include non-alphanumeric characters.

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- Pick a password you can remember.

The following are recommendations for password cracker software that you can use to determine the strength of a password.

- John The Ripper. A fast and flexible password cracking program. It allows the use of multiple word lists and is capable of brute-force password cracking. It is available online at http://www.openwall.com/john/.
- Crack. Perhaps the most well-known password cracking software, Crack is also very fast, though not as easy to use as John The Ripper. It can be found online at https://dropsafe.crypticide.com/alecm/software/crack/c50-faq.html.

The security of the entire system depends on the strength of the root password. This password should be at least 12 characters long and include a mix of capitalized letters, lowercase letters, special characters, and numbers. It should not be based on any dictionary word.

Password expiration parameters should be configured. The following commands must be run as `root` or using `sudo`.

Ensure the following line exists within the file `/etc/libuser.conf` under the `[import]` section.

```
login_defs = /etc/login.defs
```

Ensure no lines in the `[userdefaults]` section begin with the following text, as these words override settings from `/etc/login.defs`:

- `LU_SHADOWMAX`
- `LU_SHADOWMIN`
- `LU_SHADOWWARNING`

Ensure the following command produces no output. Any accounts listed by running this command should be locked.

```
grep "^+:" /etc/passwd /etc/shadow /etc/group
```

Note: We strongly recommend that customers change their passwords after initial setup.

```
cd /etc
chown root:root passwd shadow group gshadow
chmod 644 passwd group
chmod 400 shadow gshadow
```

Find all the files that are world-writable and that do not have their sticky bits set.

```
find / -xdev -type d \( -perm -0002 -a ! -perm -1000 \) -print
```

Set the sticky bit (`# chmod +t {dir}`) for all the directories that result from running the previous command.

Find all the files that are world-writable and fix each file listed.

```
find / -xdev -type f -perm -0002 -print
```

Set the right permissions (`# chmod o-w {file}`) for all the files generated by running the aforementioned command.

Find all the files that do not belong to a valid user or group and either assign an owner or remove the file, as appropriate.

```
find / -xdev \( -nouser -o -nogroup \) -print
```

Find all the directories that are world-writable and ensure they are owned by either root or a system account (assuming only system accounts have a User ID lower than 500). If the command generates any output, verify the assignment is correct or reassign it to root.

```
find / -xdev -type d -perm -0002 -uid +500 -print
```

Authentication settings such as password quality, password expiration policy, password reuse, password retry attempts, and more can be configured using the Pluggable Authentication Modules (PAM) framework. PAM looks in the directory `/etc/pam.d` for application-specific configuration information. Running `authconfig` or `system-config-authentication` will re-write the PAM configuration files, destroying any manually made changes and replacing them with system defaults.

The default `pam_cracklib` PAM module provides strength checking for passwords. To configure `pam_cracklib` to require at least one uppercase character, lowercase character, digit, and special character, as recommended by the U.S. Department of Defense guidelines, edit the file `/etc/pam.d/system-auth` to include the following parameters in the line corresponding to password requisite `pam_cracklib.so try_first_pass`.

```
retry=3:
dcredit=-1. Require at least one digit
ucredit=-1. Require at least one upper case character
ocredit=-1. Require at least one special character
lcredit=-1. Require at least one lower case character
minlen=14. Require a minimum password length of 14.
```

For example:

```
password required pam_cracklib.so try_first_pass retry=3\minlen=14 dcredit=-1 ucredit=-1 ocredit=-1 lcredit=-1
```

These parameters can be set to reflect your security policy requirements. Note that the password restrictions are not applicable to the root password.

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The `pam_tally2` PAM module provides the capability to lock out user accounts after a specified number of failed login attempts. To enforce password lockout, edit the file `/etc/pam.d/system-auth` to include the following lines:

- The first of the auth lines should include:

```
auth required pam_tally2.so deny=5 onerr=fail unlock_time=900
```

- The first of the account lines should include:

```
account required pam_tally2.so
```

Here, the deny parameter is set to limit the number of retries to 5 and the `unlock_time` has been set to 900 seconds to keep the account locked for 900 seconds before it is unlocked. These parameters may be configured appropriately to reflect your security policy requirements. A locked account can be manually unlocked using the `pam_tally2` utility:

```
/sbin/pam_tally2 --user {username} --reset
```

You can use PAM to limit the reuse of recent passwords. The remember option for the `pam_ unix` module can be set to remember the recent passwords and prevent their reuse. To accomplish this, edit the appropriate line in `/etc/pam.d/system-auth` to include the remember option.

For example:

```
password sufficient pam_unix.so [ … existing_options …]
remember=5
```

You can set the number of previous passwords to remember to appropriately reflect your security policy requirements.

```
cd /etc
chown root:root passwd shadow group gshadow
chmod 644 passwd group
chmod 400 shadow gshadow
```

Parent topic: WarehousePG Security Configuration Guide

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6 WarehousePG best practices

A best practice is a method or technique that has consistently shown results superior to those achieved with other means. Best practices are found through experience and are proven to reliably lead to a desired result. Best practices are a commitment to use any product correctly and optimally, by leveraging all the knowledge and expertise available to ensure success.

This document does not teach you how to use WarehousePG features. Links are provided to other relevant parts of the WarehousePG documentation for information on how to use and implement specific WarehousePG features. This document addresses the most important best practices to follow when designing, implementing, and using WarehousePG.

It is not the intent of this document to cover the entire product or compendium of features, but rather to provide a summary of *what matters most* in WarehousePG. This document does not address *edge* use cases. While edge use cases can further leverage and benefit from WarehousePG features, they require a proficient knowledge and expertise with these features, as well as a deep understanding of your environment, including SQL access, query execution, concurrency, workload, and other factors.

By following these best practices, you will increase the success of your WarehousePG clusters in the areas of maintenance, support, performance, and scalability.

- Best Practices Summary
  A summary of best practices for WarehousePG.
- System Configuration
  Requirements and best practices for system administrators who are configuring WarehousePG cluster hosts.
- Schema Design
  Best practices for designing WarehousePG schemas.
- Memory and Resource Management with Resource Groups
  Managing WarehousePG resources with resource groups.
- Memory and Resource Management with Resource Queues
  Avoid memory errors and manage WarehousePG resources.
- System Monitoring and Maintenance
  Best practices for regular maintenance that will ensure WarehousePG high availability and optimal performance.
- Loading Data
  Description of the different ways to add data to WarehousePG.
- Security
  Best practices to ensure the highest level of system security.
- Encrypting Data and Database Connections
  Best practices for implementing encryption and managing keys.
- Tuning SQL Queries
  The WarehousePG cost-based optimizer evaluates many strategies for running a query and chooses the least costly method.
- High Availability
  WarehousePG supports highly available, fault-tolerant database services when you enable and properly configure WarehousePG high availability features. To guarantee a required level of service, each component must have a standby ready to take its place if it should fail.

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6.1 Best Practices Summary

A summary of best practices for WarehousePG.

Data Model

WarehousePG is an analytical MPP shared-nothing database. This model is significantly different from a highly normalized/transactional SMP database. Because of this, the following best practices are recommended.

- WarehousePG performs best with a denormalized schema design suited for MPP analytical processing for example, Star or Snowflake schema, with large fact tables and smaller dimension tables.
- Use the same data types for columns used in joins between tables.

See Schema Design.

Heap vs. Append-Optimized Storage

- Use heap storage for tables and partitions that will receive iterative batch and singleton `UPDATE`, `DELETE`, and `INSERT` operations.
- Use heap storage for tables and partitions that will receive concurrent `UPDATE`, `DELETE`, and `INSERT` operations.
- Use append-optimized storage for tables and partitions that are updated infrequently after the initial load and have subsequent inserts only performed in large batch operations.
- Avoid performing singleton `INSERT`, `UPDATE`, or `DELETE` operations on append-optimized tables.
- Avoid performing concurrent batch `UPDATE` or `DELETE` operations on append-optimized tables. Concurrent batch `INSERT` operations are acceptable.

See Heap Storage or Append-Optimized Storage.

Row vs. Column Oriented Storage

- Use row-oriented storage for workloads with iterative transactions where updates are required and frequent inserts are performed.
- Use row-oriented storage when selects against the table are wide.
- Use row-oriented storage for general purpose or mixed workloads.
- Use column-oriented storage where selects are narrow and aggregations of data are computed over a small number of columns.
- Use column-oriented storage for tables that have single columns that are regularly updated without modifying other columns in the row.

See Row or Column Orientation.

Compression

- Use compression on large append-optimized and partitioned tables to improve I/O across the system.
- Set the column compression settings at the level where the data resides.
- Balance higher levels of compression with the time and CPU cycles needed to compress and uncompress data.

See Compression.

Distributions

- Explicitly define a column or random distribution for all tables. Do not use the default.
- Use a single column that will distribute data across all segments evenly.
- Do not distribute on columns that will be used in the `WHERE` clause of a query.
- Do not distribute on dates or timestamps.
- Never distribute and partition tables on the same column.
- Achieve local joins to significantly improve performance by distributing on the same column for large tables commonly joined together.
- To ensure there is no data skew, validate that data is evenly distributed after the initial load and after incremental loads.

See Distributions.

Resource Queue Memory Management

- Set `vm.overcommit_memory` to 2.
- Do not configure the OS to use huge pages.
- Use `gp_vmem_protect_limit` to set the maximum memory that the instance can allocate for *all* work being done in each segment database.

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- You can use `gp_vmem_protect_limit` by calculating:
  - `gp_vmem` – the total memory available to WarehousePG
    - If the total system memory is less than 256 GB, use this formula:

      ```
      gp_vmem = ((SWAP + RAM) – (7.5GB + 0.05 * RAM)) / 1.7
      ```

    - If the total system memory is equal to or greater than 256 GB, use this formula:

      ```
      gp_vmem = ((SWAP + RAM) – (7.5GB + 0.05 * RAM)) / 1.17
      ```

    where `SWAP` is the host's swap space in GB, and `RAM` is the host's RAM in GB.
  - `max_acting_primary_segments` – the maximum number of primary segments that could be running on a host when mirror segments are activated due to a host or segment failure.
  - `gp_vmem_protect_limit`

    ```
    gp_vmem_protect_limit = gp_vmem / acting_primary_segments
    ```

    Convert to MB to set the value of the configuration parameter.
- In a scenario where a large number of workfiles are generated calculate the `gp_vmem` factor with this formula to account for the workfiles.
  - If the total system memory is less than 256 GB:

    ```
    gp_vmem = ((SWAP + RAM) – (7.5GB + 0.05 * RAM – (300KB *
          total_#_workfiles))) / 1.7
    ```

  - If the total system memory is equal to or greater than 256 GB:

    ```
    gp_vmem = ((SWAP + RAM) – (7.5GB + 0.05 * RAM – (300KB *
          total_#_workfiles))) / 1.17
    ```

- Never set `gp_vmem_protect_limit` too high or larger than the physical RAM on the system.
- Use the calculated `gp_vmem` value to calculate the setting for the `vm.overcommit_ratio` operating system parameter:

  ```
  vm.overcommit_ratio = (RAM – 0.026 * gp_vmem) / RAM
  ```

- Use `statement_mem` to allocate memory used for a query per segment db.
- Use resource queues to set both the numbers of active queries (`ACTIVE_STATEMENTS`) and the amount of memory (`MEMORY_LIMIT`) that can be utilized by queries in the queue.
- Associate all users with a resource queue. Do not use the default queue.
- Set `PRIORITY` to match the real needs of the queue for the workload and time of day. Avoid using MAX priority.
- Ensure that resource queue memory allocations do not exceed the setting for `gp_vmem_protect_limit`.
- Dynamically update resource queue settings to match daily operations flow.

See Setting the WarehousePG Recommended OS Parameters and Memory and Resource Management with Resource Queues.

Partitioning

- Partition large tables only. Do not partition small tables.
- Use partitioning only if partition elimination (partition pruning) can be achieved based on the query criteria.
- Choose range partitioning over list partitioning.
- Partition the table based on a commonly-used column, such as a date column.
- Never partition and distribute tables on the same column.
- Do not use default partitions.
- Do not use multi-level partitioning; create fewer partitions with more data in each partition.
- Validate that queries are selectively scanning partitioned tables (partitions are being eliminated) by examining the query `EXPLAIN` plan.
- Do not create too many partitions with column-oriented storage because of the total number of physical files on every segment: `physical files = segments x columns x partitions`

See Partitioning.

Indexes

- In general indexes are not needed in WarehousePG.
- Create an index on a single column of a columnar table for drill-through purposes for high cardinality tables that require queries with high selectivity.
- Do not index columns that are frequently updated.
- Consider dropping indexes before loading data into a table. After the load, re-create the indexes for the table.
- Create selective B-tree indexes.
- Do not create bitmap indexes on columns that are updated.
- Avoid using bitmap indexes for unique columns, very high or very low cardinality data. Bitmap indexes perform best when the column has a low cardinality—100 to 100,000 distinct values.
- Do not use bitmap indexes for transactional workloads.
- In general do not index partitioned tables. If indexes are needed, the index columns must be different than the partition columns.

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See Indexes.

Resource Queues

- Use resource queues to manage the workload on the cluster.
- Associate all roles with a user-defined resource queue.
- Use the `ACTIVE_STATEMENTS` parameter to limit the number of active queries that members of the particular queue can run concurrently.
- Use the `MEMORY_LIMIT` parameter to control the total amount of memory that queries running through the queue can utilize.
- Alter resource queues dynamically to match the workload and time of day.

See Configuring Resource Queues.

Monitoring and Maintenance

- Implement the "Recommended Monitoring and Maintenance Tasks" in the *WarehousePG Administrator Guide*.
- Run `gpcheckperf` at install time and periodically thereafter, saving the output to compare system performance over time.
- Use all the tools at your disposal to understand how your system behaves under different loads.
- Examine any unusual event to determine the cause.
- Monitor query activity on the system by running explain plans periodically to ensure the queries are running optimally.
- Review plans to determine whether index are being used and partition elimination is occurring as expected.
- Know the location and content of system log files and monitor them on a regular basis, not just when problems arise.

See System Monitoring and Maintenance, Query Profiling and Monitoring WarehousePG Log Files.

ANALYZE

- Determine if analyzing the database is actually needed. Analyzing is not needed if `gp_autostats_mode` is set to `on_no_stats` (the default) and the table is not partitioned.
- Use `analyzedb` in preference to `ANALYZE` when dealing with large sets of tables, as it does not require analyzing the entire database. The `analyzedb` utility updates statistics data for the specified tables incrementally and concurrently. For append optimized tables, `analyzedb` updates statistics incrementally only if the statistics are not current. For heap tables, statistics are always updated. `ANALYZE` does not update the table metadata that the `analyzedb` utility uses to determine whether table statistics are up to date.
- Selectively run `ANALYZE` at the table level when needed.
- Always run `ANALYZE` after `INSERT`, `UPDATE`. and `DELETE` operations that significantly changes the underlying data.
- Always run `ANALYZE` after `CREATE INDEX` operations.
- If `ANALYZE` on very large tables takes too long, run `ANALYZE` only on the columns used in a join condition, `WHERE` clause, `SORT`, `GROUP BY`, or `HAVING` clause.
- When dealing with large sets of tables, use `analyzedb` instead of `ANALYZE.`
- Run `analyzedb` on the root partition any time that you add a new partition(s) to a partitioned table. This operation both analyzes the leaf partitions in parallel and merges any updated statistics into the root partition.

See Updating Statistics with ANALYZE.

Vacuum

- Run `VACUUM` after large `UPDATE` and `DELETE` operations.
- Do not run `VACUUM FULL`. Instead run a `CREATE TABLE...AS` operation, then rename and drop the original table.
- Frequently run `VACUUM` on the system catalogs to avoid catalog bloat and the need to run `VACUUM FULL` on catalog tables.
- Never issue a `kill` command against `VACUUM` on catalog tables.

See Managing Bloat in a Database.

Loading

- Maximize the parallelism as the number of segments increase.
- Spread the data evenly across as many ETL nodes as possible.
  - Split very large data files into equal parts and spread the data across as many file systems as possible.
  - Run two `gpfdist` instances per file system.
  - Run `gpfdist` on as many interfaces as possible.
  - Use `gp_external_max_segs` to control the number of segments that will request data from the `gpfdist` process.
  - Always keep `gp_external_max_segs` and the number of `gpfdist` processes an even factor.

- Always drop indexes before loading into existing tables and re-create the index after loading.
- Run `VACUUM` after load errors to recover space.

See Loading Data.

Security

- Secure the `gpadmin` user id and only allow essential system administrators access to it.
- Administrators should only log in to WarehousePG as `gpadmin` when performing certain system maintenance tasks (such as upgrade or expansion).
- Limit users who have the `SUPERUSER` role attribute. Roles that are superusers bypass all access privilege checks in WarehousePG, as well as resource queuing. Only system administrators should be given superuser rights. See "Altering Role Attributes" in the *WarehousePG Administrator Guide*.
- Database users should never log on as `gpadmin`, and ETL or production workloads should never run as `gpadmin`.
- Assign a distinct WarehousePG role to each user, application, or service that logs in.
- For applications or web services, consider creating a distinct role for each application or service.
- Use groups to manage access privileges.
- Protect the root password.
- Enforce a strong password password policy for operating system passwords.
- Ensure that important operating system files are protected.

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See Security.

Encryption

- Encrypting and decrypting data has a performance cost; only encrypt data that requires encryption.
- Do performance testing before implementing any encryption solution in a production system.
- Server certificates in a production WarehousePG cluster should be signed by a certificate authority (CA) so that clients can authenticate the server. The CA may be local if all clients are local to the organization.
- Client connections to WarehousePG should use SSL encryption whenever the connection goes through an insecure link.
- A symmetric encryption scheme, where the same key is used to both encrypt and decrypt, has better performance than an asymmetric scheme and should be used when the key can be shared safely.
- Use cryptographic functions to encrypt data on disk. The data is encrypted and decrypted in the database process, so it is important to secure the client connection with SSL to avoid transmitting unencrypted data.
- Use the gpfdists protocol to secure ETL data as it is loaded into or unloaded from the database.

See Encrypting Data and Database Connections

High Availability

> **Note** The following guidelines apply to actual hardware deployments, but not to public cloud-based infrastructure, where high availability solutions may already exist.

- Use a hardware RAID storage solution with 8 to 24 disks.
- Use RAID 1, 5, or 6 so that the disk array can tolerate a failed disk.
- Configure a hot spare in the disk array to allow rebuild to begin automatically when disk failure is detected.
- Protect against failure of the entire disk array and degradation during rebuilds by mirroring the RAID volume.
- Monitor disk utilization regularly and add additional space when needed.
- Monitor segment skew to ensure that data is distributed evenly and storage is consumed evenly at all segments.
- Set up a standby coordinator instance to take over if the primary coordinator fails.
- Plan how to switch clients to the new coordinator instance when a failure occurs, for example, by updating the coordinator address in DNS.
- Set up monitoring to send notifications in a system monitoring application or by email when the primary fails.
- Set up mirrors for all segments.
- Locate primary segments and their mirrors on different hosts to protect against host failure.
- Recover failed segments promptly, using the `gprecoverseg` utility, to restore redundancy and return the system to optimal balance.
- Consider a Dual Cluster configuration to provide an additional level of redundancy and additional query processing throughput.
- Backup WarehousePGs regularly unless the data is easily restored from sources.
- If backups are saved to local cluster storage, move the files to a safe, off-cluster location when the backup is complete.
- If backups are saved to NFS mounts, use a scale-out NFS solution such as Dell PowerScale (Isilon) to prevent IO bottlenecks.

See High Availability.

Parent topic: WarehousePG Best Practices

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6.2 System Configuration

Requirements and best practices for system administrators who are configuring WarehousePG cluster hosts.

Configuration of the WarehousePG cluster is usually performed as root.

Configuring the Timezone

WarehousePG selects a timezone to use from a set of internally stored PostgreSQL timezones. The available PostgreSQL timezones are taken from the Internet Assigned Numbers Authority (IANA) Time Zone Database, and WarehousePG updates its list of available timezones as necessary when the IANA database changes for PostgreSQL.

WarehousePG selects the timezone by matching a PostgreSQL timezone with the user specified time zone, or the host system time zone if no time zone is configured. For example, when selecting a default timezone, WarehousePG uses an algorithm to select a PostgreSQL timezone based on the host system timezone files. If the system timezone includes leap second information, WarehousePG cannot match the system timezone with a PostgreSQL timezone. In this case, WarehousePG calculates a "best match" with a PostgreSQL timezone based on information from the host system.

As a best practice, configure WarehousePG and the host systems to use a known, supported timezone. This sets the timezone for the WarehousePG coordinator and segment instances, and prevents WarehousePG from recalculating a "best match" timezone each time the cluster is restarted, using the current system timezone and WarehousePG timezone files (which may have been updated from the IANA database since the last restart). Use the `gpconfig` utility to show and set the WarehousePG timezone. For example, these commands show the WarehousePG timezone and set the timezone to `US/Pacific`.

```
# gpconfig -s TimeZone
# gpconfig -c TimeZone -v 'US/Pacific'
```

You must restart WarehousePG after changing the timezone. The command `gpstop -ra` restarts WarehousePG. The catalog view `pg_timezone_names` provides WarehousePG timezone information.

File System

XFS is the file system used for WarehousePG data directories. Use the mount options described in Configure Operating System.

Port Configuration

See the recommended OS parameter settings in the *WarehousePG Installation Guide* for further details.

Set up `ip_local_port_range` so it does not conflict with the WarehousePG port ranges. For example, setting this range in `/etc/sysctl.conf`:

```
net.ipv4.ip_local_port_range = 10000  65535
```

you could set the WarehousePG base port numbers to these values.

```
PORT_BASE = 6000
MIRROR_PORT_BASE = 7000
```

See the Recommended OS Parameters Settings in the *WarehousePG Installation Guide* for further details.

I/O Configuration

Set the blockdev read-ahead size to 16384 on the devices that contain data directories. This command sets the read-ahead size for `/dev/sdb`.

```
# /sbin/blockdev --setra 16384 /dev/sdb
```

This command returns the read-ahead size for `/dev/sdb`.

```
# /sbin/blockdev --getra /dev/sdb
16384
```

See the Recommended OS Parameters Settings in the *WarehousePG Installation Guide* for further details.

The deadline IO scheduler should be set for all data directory devices.

```
 # cat /sys/block/sdb/queue/scheduler
 noop anticipatory [deadline] cfq
```

The maximum number of OS files and processes should be increased in the `/etc/security/limits.conf` file.

```
* soft  nofile 524288
* hard  nofile 524288
* soft  nproc 131072
* hard  nproc 131072
```

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OS Memory Configuration

The Linux sysctl `vm.overcommit_memory` and `vm.overcommit_ratio` variables affect how the operating system manages memory allocation. See the `/etc/sysctl.conf` file parameters guidelines in the *WarehousePG Datatabase Installation Guide* for further details.

`vm.overcommit_memory` determines the method the OS uses for determining how much memory can be allocated to processes. This should be always set to 2, which is the only safe setting for the database.

> **Note** For information on configuration of overcommit memory, refer to:

- https://en.wikipedia.org/wiki/Memory_overcommitment
- https://www.kernel.org/doc/Documentation/vm/overcommit-accounting

`vm.overcommit_ratio` is the percent of RAM that is used for application processes. The default is 50 on Red Hat Enterprise Linux. See Resource Queue Segment Memory Configuration for a formula to calculate an optimal value.

Do not enable huge pages in the operating system.

See also Memory and Resource Management with Resource Queues.

Shared Memory Settings

WarehousePG uses shared memory to communicate between `postgres` processes that are part of the same `postgres` instance. The following shared memory settings should be set in `sysctl` and are rarely modified. See the `sysctl.conf` file parameters in the *WarehousePG Installation Guide* for further details.

```
kernel.shmmax = 810810728448
kernel.shmmni = 4096
kernel.shmall = 197951838
```

See Setting the WarehousePG Recommended OS Parameters for more details.

Number of Segments per Host

Determining the number of segments to run on each segment host has immense impact on overall system performance. The segments share the host's CPU cores, memory, and NICs with each other and with other processes running on the host. Over-estimating the number of segments a server can accommodate is a common cause of suboptimal performance.

The factors that must be considered when choosing how many segments to run per host include the following:

- Number of cores
- Amount of physical RAM installed in the server
- Number of NICs
- Amount of storage attached to server
- Mixture of primary and mirror segments
- ETL processes that will run on the hosts
- Non-WarehousePG processes running on the hosts

Resource Queue Segment Memory Configuration

The `gp_vmem_protect_limit` server configuration parameter specifies the amount of memory that all active postgres processes for a single segment can consume at any given time. Queries that exceed this amount will fail. Use the following calculations to estimate a safe value for `gp_vmem_protect_limit`.

1. Calculate `gp_vmem`, the host memory available to WarehousePG.
    - If the total system memory is less than 256 GB, use this formula:

      ```
      gp_vmem = ((SWAP + RAM) – (7.5GB + 0.05 * RAM)) / 1.7
      ```

    - If the total system memory is equal to or greater than 256 GB, use this formula:

      ```
      gp_vmem = ((SWAP + RAM) – (7.5GB + 0.05 * RAM)) / 1.17
      ```

    where `SWAP` is the host's swap space in GB and `RAM` is the RAM installed on the host in GB.
2. Calculate `max_acting_primary_segments`. This is the maximum number of primary segments that can be running on a host when mirror segments are activated due to a segment or host failure on another host in the cluster. With mirrors arranged in a 4-host block with 8 primary segments per host, for example, a single segment host failure would activate two or three mirror segments on each remaining host in the failed host's block. The `max_acting_primary_segments` value for this configuration is 11 (8 primary segments plus 3 mirrors activated on failure).
3. Calculate `gp_vmem_protect_limit` by dividing the total WarehousePG memory by the maximum number of acting primaries:

    ```
    gp_vmem_protect_limit = gp_vmem / max_acting_primary_segments
    ```

    Convert to megabytes to find the value to set for the `gp_vmem_protect_limit` system configuration parameter.

For scenarios where a large number of workfiles are generated, adjust the calculation for `gp_vmem` to account for the workfiles.

- If the total system memory is less than 256 GB:

  ```
  gp_vmem = ((SWAP + RAM) – (7.5GB + 0.05 * RAM – (300KB * total_#_workfiles))) / 1.7
  ```

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- If the total system memory is equal to or greater than 256 GB:

```
gp_vmem = ((SWAP + RAM) – (7.5GB + 0.05 * RAM – (300KB * total_#_workfiles))) / 1.17
```

For information about monitoring and managing workfile usage, see the *WarehousePG Administrator Guide*.

You can calculate the value of the `vm.overcommit_ratio` operating system parameter from the value of `gp_vmem`:

```
vm.overcommit_ratio = (RAM – 0.026 * gp_vmem) / RAM
```

See OS Memory Configuration for more about about `vm.overcommit_ratio`.

See also Memory and Resource Management with Resource Queues.

Resource Queue Statement Memory Configuration

The `statement_mem` server configuration parameter is the amount of memory to be allocated to any single query in a segment database. If a statement requires additional memory it will spill to disk. Calculate the value for `statement_mem` with the following formula:

```
(gp_vmem_protect_limit * .9) / max_expected_concurrent_queries
```

For example, for 40 concurrent queries with `gp_vmem_protect_limit` set to 8GB (8192MB), the calculation for `statement_mem` would be:

```
(8192MB * .9) / 40 = 184MB
```

Each query would be allowed 184MB of memory before it must spill to disk.

To increase `statement_mem` safely you must either increase `gp_vmem_protect_limit` or reduce the number of concurrent queries. To increase `gp_vmem_protect_limit`, you must add physical RAM and/or swap space, or reduce the number of segments per host.

Note that adding segment hosts to the cluster cannot help out-of-memory errors unless you use the additional hosts to decrease the number of segments per host.

Spill files are created when there is not enough memory to fit all the mapper output, usually when 80% of the buffer space is occupied.

Also, see Resource Management for best practices for managing query memory using resource queues.

Resource Queue Spill File Configuration

WarehousePG creates *spill files* (also called *workfiles*) on disk if a query is allocated insufficient memory to run in memory. A single query can create no more than 100,000 spill files, by default, which is sufficient for the majority of queries.

You can control the maximum number of spill files created per query and per segment with the configuration parameter `gp_workfile_limit_files_per_query`. Set the parameter to 0 to allow queries to create an unlimited number of spill files. Limiting the number of spill files permitted prevents run-away queries from disrupting the system.

A query could generate a large number of spill files if not enough memory is allocated to it or if data skew is present in the queried data. If a query creates more than the specified number of spill files, WarehousePG returns this error:

```
ERROR: number of workfiles per query limit exceeded
```

Before raising the `gp_workfile_limit_files_per_query`, try reducing the number of spill files by changing the query, changing the data distribution, or changing the memory configuration.

The `gp_toolkit` schema includes views that allow you to see information about all the queries that are currently using spill files. This information can be used for troubleshooting and for tuning queries:

- The `gp_workfile_entries` view contains one row for each operator using disk space for workfiles on a segment at the current time. See How to Read Explain Plans for information about operators.
- The `gp_workfile_usage_per_query` view contains one row for each query using disk space for workfiles on a segment at the current time.
- The `gp_workfile_usage_per_segment` view contains one row for each segment. Each row displays the total amount of disk space used for workfiles on the segment at the current time.

See the *WarehousePG Reference Guide* for descriptions of the columns in these views.

The `gp_workfile_compression` configuration parameter specifies whether the spill files are compressed. It is `off` by default. Enabling compression can improve performance when spill files are used.

Parent topic: WarehousePG Best Practices

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6.3 Schema Design

Best practices for designing WarehousePG schemas.

WarehousePG is an analytical, shared-nothing database, which is much different than a highly normalized, transactional SMP database. WarehousePG performs best with a denormalized schema design suited for MPP analytical processing, a star or snowflake schema, with large centralized fact tables connected to multiple smaller dimension tables.

Parent topic: WarehousePG Best Practices

Data Types

Use Types Consistently

Use the same data types for columns used in joins between tables. If the data types differ, WarehousePG must dynamically convert the data type of one of the columns so the data values can be compared correctly. With this in mind, you may need to increase the data type size to facilitate joins to other common objects.

Choose Data Types that Use the Least Space

You can increase database capacity and improve query execution by choosing the most efficient data types to store your data.

Use `TEXT` or `VARCHAR` rather than `CHAR`. There are no performance differences among the character data types, but using `TEXT` or `VARCHAR` can decrease the storage space used.

Use the smallest numeric data type that will accommodate your data. Using `BIGINT` for data that fits in `INT` or `SMALLINT` wastes storage space.

Storage Model

WarehousePG provides an array of storage options when creating tables. It is very important to know when to use heap storage versus append-optimized (AO) storage, and when to use row-oriented storage versus column-oriented storage. The correct selection of heap versus AO and row versus column is extremely important for large fact tables, but less important for small dimension tables.

The best practices for determining the storage model are:

1. Design and build an insert-only model, truncating a daily partition before load.
2. For large partitioned fact tables, evaluate and use optimal storage options for different partitions. One storage option is not always right for the entire partitioned table. For example, some partitions can be row-oriented while others are column-oriented.
3. When using column-oriented storage, every column is a separate file on *every* WarehousePG segment. For tables with a large number of columns consider columnar storage for data often accessed (hot) and row-oriented storage for data not often accessed (cold).
4. Storage options should be set at the partition level.
5. Compress large tables to improve I/O performance and to make space in the cluster.

Heap Storage or Append-Optimized Storage

Heap storage is the default model, and is the model PostgreSQL uses for all database tables. Use heap storage for tables and partitions that will receive iterative `UPDATE`, `DELETE`, and singleton `INSERT` operations. Use heap storage for tables and partitions that will receive concurrent `UPDATE`, `DELETE`, and `INSERT` operations.

Use append-optimized storage for tables and partitions that are updated infrequently after the initial load and have subsequent inserts performed only in batch operations. Avoid performing singleton `INSERT`, `UPDATE`, or `DELETE` operations on append-optimized tables. Concurrent batch `INSERT` operations are acceptable, but *never* perform concurrent batch `UPDATE` or `DELETE` operations.

The append-optimized storage model is inappropriate for frequently updated tables, because space occupied by rows that are updated and deleted in append-optimized tables is not recovered and reused as efficiently as with heap tables. Append-optimized storage is intended for large tables that are loaded once, updated infrequently, and queried frequently for analytical query processing.

Row or Column Orientation

Row orientation is the traditional way to store database tuples. The columns that comprise a row are stored on disk contiguously, so that an entire row can be read from disk in a single I/O.

Column orientation stores column values together on disk. A separate file is created for each column. If the table is partitioned, a separate file is created for each column and partition. When a query accesses only a small number of columns in a column-oriented table with many columns, the cost of I/O is substantially reduced compared to a row-oriented table; any columns not referenced do not have to be retrieved from disk.

Row-oriented storage is recommended for transactional type workloads with iterative transactions where updates are required and frequent inserts are performed. Use row-oriented storage when selects against the table are wide, where many columns of a single row are needed in a query. If the majority of columns in the `SELECT` list or `WHERE` clause is selected in queries, use row-oriented storage. Use row-oriented storage for general purpose or mixed workloads, as it offers the best combination of flexibility and performance.

Column-oriented storage is optimized for read operations but it is not optimized for write operations; column values for a row must be written to different places on disk. Column-oriented tables can offer optimal query performance on large tables with many columns where only a small subset of columns are accessed by the queries.

Another benefit of column orientation is that a collection of values of the same data type can be stored together in less space than a collection of mixed type values, so column-oriented tables use less disk space (and consequently less disk I/O) than row-oriented tables. Column-oriented tables also compress better than row-oriented tables.

Use column-oriented storage for data warehouse analytic workloads where selects are narrow or aggregations of data are computed over a small number of columns. Use column-oriented storage for tables that have single columns that are regularly updated without modifying other columns in the row. Reading a complete row in a wide columnar table requires more time than reading the same row from a row-oriented table. It is important to understand that each column is a separate physical file on *every* segment in WarehousePG.

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Compression

WarehousePG offers a variety of options to compress append-optimized tables and partitions. Use compression to improve I/O across the system by allowing more data to be read with each disk read operation. The best practice is to set the column compression settings at the partition level.

Note that new partitions added to a partitioned table do not automatically inherit compression defined at the table level; you must *specifically* define compression when you add new partitions.

Run-length encoding (RLE) compression provides the best levels of compression. Higher levels of compression usually result in more compact storage on disk, but require additional time and CPU cycles when compressing data on writes and uncompressing on reads. Sorting data, in combination with the various compression options, can achieve the highest level of compression.

Data compression should never be used for data that is stored on a compressed file system.

Test different compression types and ordering methods to determine the best compression for your specific data. For example, you might start zstd compression at level 8 or 9 and adjust for best results. RLE compression works best with files that contain repetitive data.

Distributions

An optimal distribution that results in evenly distributed data is the most important factor in WarehousePG. In an MPP shared nothing environment overall response time for a query is measured by the completion time for all segments. The system is only as fast as the slowest segment. If the data is skewed, segments with more data will take more time to complete, so every segment must have an approximately equal number of rows and perform approximately the same amount of processing. Poor performance and out of memory conditions may result if one segment has significantly more data to process than other segments.

Consider the following best practices when deciding on a distribution strategy:

- Explicitly define a column or random distribution for all tables. Do not use the default.
- Ideally, use a single column that will distribute data across all segments evenly.
- Do not distribute on columns that will be used in the `WHERE` clause of a query.
- Do not distribute on dates or timestamps.
- The distribution key column data should contain unique values or very high cardinality.
- If a single column cannot achieve an even distribution, use a multi-column distribution key with a maximum of two columns. Additional column values do not typically yield a more even distribution and they require additional time in the hashing process.
- If a two-column distribution key cannot achieve an even distribution of data, use a random distribution. Multi-column distribution keys in most cases require motion operations to join tables, so they offer no advantages over a random distribution.

WarehousePG random distribution is not round-robin, so there is no guarantee of an equal number of records on each segment. Random distributions typically fall within a target range of less than ten percent variation.

Optimal distributions are critical when joining large tables together. To perform a join, matching rows must be located together on the same segment. If data is not distributed on the same join column, the rows needed from one of the tables are dynamically redistributed to the other segments. In some cases a broadcast motion, in which each segment sends its individual rows to all other segments, is performed rather than a redistribution motion, where each segment rehashes the data and sends the rows to the appropriate segments according to the hash key.

Local (Co-located) Joins

Using a hash distribution that evenly distributes table rows across all segments and results in local joins can provide substantial performance gains. When joined rows are on the same segment, much of the processing can be accomplished within the segment instance. These are called *local* or *co-located* joins. Local joins minimize data movement; each segment operates independently of the other segments, without network traffic or communications between segments.

To achieve local joins for large tables commonly joined together, distribute the tables on the same column. Local joins require that both sides of a join be distributed on the same columns (and in the same order) *and* that all columns in the distribution clause are used when joining tables. The distribution columns must also be the same data type—although some values with different data types may appear to have the same representation, they are stored differently and hash to different values, so they are stored on different segments.

Data Skew

Data skew is often the root cause of poor query performance and out of memory conditions. Skewed data affects scan (read) performance, but it also affects all other query execution operations, for instance, joins and group by operations.

It is very important to *validate* distributions to *ensure* that data is evenly distributed after the initial load. It is equally important to *continue* to validate distributions after incremental loads.

The following query shows the number of rows per segment as well as the variance from the minimum and maximum numbers of rows:

```
SELECT 'Example Table' AS "Table Name",
    max(c) AS "Max Seg Rows", min(c) AS "Min Seg Rows",
    (max(c)-min(c))*100.0/max(c) AS "Percentage Difference Between Max & Min"
FROM (SELECT count(*) c, gp_segment_id FROM facts GROUP BY 2) AS a;
```

The `gp_toolkit` schema has two views that you can use to check for skew.

- The `gp_toolkit.gp_skew_coefficients` view shows data distribution skew by calculating the coefficient of variation (CV) for the data stored on each segment. The `skccoeff` column shows the coefficient of variation (CV), which is calculated as the standard deviation divided by the average. It takes into account both the average and variability around the average of a data series. The lower the value, the better. Higher values indicate greater data skew.
- The `gp_toolkit.gp_skew_idle_fractions` view shows data distribution skew by calculating the percentage of the system that is idle during a table scan, which is an indicator of computational skew. The `siffraction` column shows the percentage of the system that is idle during a table scan. This is an indicator of uneven data distribution or query processing skew. For example, a value of 0.1 indicates 10% skew, a value of 0.5 indicates 50% skew, and so on. Tables that have more than10% skew should have their distribution policies evaluated.

Processing Skew

Processing skew results when a disproportionate amount of data flows to, and is processed by, one or a few segments. It is often the culprit behind WarehousePG performance and stability issues. It can happen with operations such join, sort, aggregation, and various OLAP operations. Processing skew happens in flight while a query is running and is not as easy to detect as data skew, which is caused by uneven data distribution due to the wrong choice of distribution keys. Data skew is present at the table level, so it can be easily detected and avoided by choosing optimal distribution keys.

If single segments are failing, that is, not all segments on a host, it may be a processing skew issue. Identifying processing skew is currently a manual process. First look for spill files. If there is skew, but not enough to cause spill, it will not become a performance issue. If you determine skew exists, then find the query responsible for the skew.

The remedy for processing skew in almost all cases is to rewrite the query. Creating temporary tables can eliminate skew. Temporary tables can be randomly distributed to force a two-stage aggregation.

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Partitioning

A good partitioning strategy reduces the amount of data to be scanned by reading only the partitions needed to satisfy a query.

Each partition is a separate physical file or set of files (in the case of column-oriented tables) on *every* segment. Just as reading a complete row in a wide columnar table requires more time than reading the same row from a heap table, *reading all partitions in a partitioned table requires more time than reading the same data from a non-partitioned table*.

Following are partitioning best practices:

- Partition large tables only, do not partition small tables.
- Use partitioning on large tables *only* when partition elimination (partition pruning) can be achieved based on query criteria and is accomplished by partitioning the table based on the query predicate. Whenever possible, use range partitioning instead of list partitioning.
- The query planner can selectively scan partitioned tables only when the query contains a direct and simple restriction of the table using immutable operators, such as `=`, `<`, `<=`, `>`, `>=`, and `<>`.
- Selective scanning recognizes `STABLE` and `IMMUTABLE` functions, but does not recognize `VOLATILE` functions within a query. For example, `WHERE` clauses such as

  ```
  date > CURRENT_DATE
  ```

  cause the query planner to selectively scan partitioned tables, but a `WHERE` clause such as

  ```
  time > TIMEOFDAY
  ```

  does not. It is important to validate that queries are selectively scanning partitioned tables (partitions are being eliminated) by examining the query `EXPLAIN` plan.
- Do not use default partitions. The default partition is always scanned but, more importantly, in many environments they tend to overfill resulting in poor performance.
- *Never* partition and distribute tables on the same column.
- Do not use multi-level partitioning. While sub-partitioning is supported, it is not recommended because typically sub-partitions contain little or no data. It is a myth that performance increases as the number of partitions or sub-partitions increases; the administrative overhead of maintaining many partitions and sub-partitions will outweigh any performance benefits. For performance, scalability and manageability, balance partition scan performance with the number of overall partitions.
- Beware of using too many partitions with column-oriented storage.
- Consider workload concurrency and the average number of partitions opened and scanned for all concurrent queries.

Number of Partition and Columnar Storage Files

The only hard limit for the number of files WarehousePG supports is the operating system's open file limit. It is important, however, to consider the total number of files in the cluster, the number of files on every segment, and the total number of files on a host. In an MPP shared nothing environment, every node operates independently of other nodes. Each node is constrained by its disk, CPU, and memory. CPU and I/O constraints are not common with WarehousePG, but memory is often a limiting factor because the query execution model optimizes query performance in memory.

The optimal number of files per segment also varies based on the number of segments on the node, the size of the cluster, SQL access, concurrency, workload, and skew. There are generally six to eight segments per host, but large clusters should have fewer segments per host. When using partitioning and columnar storage it is important to balance the total number of files in the cluster, but it is *more* important to consider the number of files per segment and the total number of files on a node.

Example with 64GB Memory per Node

- Number of nodes: 16
- Number of segments per node: 8
- Average number of files per segment: 10,000

The total number of files per node is `8*10,000 = 80,000` and the total number of files for the cluster is `8*16*10,000 = 1,280,000`. The number of files increases quickly as the number of partitions and the number of columns increase.

As a general best practice, limit the total number of files per node to under 100,000. As the previous example shows, the optimal number of files per segment and total number of files per node depends on the hardware configuration for the nodes (primarily memory), size of the cluster, SQL access, concurrency, workload and skew.

Indexes

Indexes are not generally needed in WarehousePG. Most analytical queries operate on large volumes of data, while indexes are intended for locating single rows or small numbers of rows of data. In WarehousePG, a sequential scan is an efficient method to read data as each segment contains an equal portion of the data and all segments work in parallel to read the data.

If adding an index does not produce performance gains, drop it. Verify that every index you create is used by the optimizer.

For queries with high selectivity, indexes may improve query performance. Create an index on a single column of a columnar table for drill through purposes for high cardinality columns that are required for highly selective queries.

Do not index columns that are frequently updated. Creating an index on a column that is frequently updated increases the number of writes required on updates.

Indexes on expressions should be used only if the expression is used frequently in queries.

An index with a predicate creates a partial index that can be used to select a small number of rows from large tables.

Avoid overlapping indexes. Indexes that have the same leading column are redundant.

Indexes can improve performance on compressed append-optimized tables for queries that return a targeted set of rows. For compressed data, an index access method means only the necessary pages are uncompressed.

Create selective B-tree indexes. Index selectivity is a ratio of the number of distinct values a column has divided by the number of rows in a table. For example, if a table has 1000 rows and a column has 800 distinct values, the selectivity of the index is 0.8, which is considered good.

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As a general rule, drop indexes before loading data into a table. The load will run an order of magnitude faster than loading data into a table with indexes. After the load, re-create the indexes.

Bitmap indexes are suited for querying and not updating. Bitmap indexes perform best when the column has a low cardinality—100 to 100,000 distinct values. Do not use bitmap indexes for unique columns, very high, or very low cardinality data. Do not use bitmap indexes for transactional workloads.

If indexes are needed on partitioned tables, the index columns must be different than the partition columns. A benefit of indexing partitioned tables is that because the b-tree performance degrades exponentially as the size of the b-tree grows, creating indexes on partitioned tables creates smaller b-trees that perform better than with non-partitioned tables.

Column Sequence and Byte Alignment

For optimum performance lay out the columns of a table to achieve data type byte alignment. Lay out the columns in heap tables in the following order:

1. Distribution and partition columns
2. Fixed numeric types
3. Variable data types

Lay out the data types from largest to smallest, so that `BIGINT` and `TIMESTAMP` come before `INT` and `DATE`, and all of these types come before `TEXT`, `VARCHAR`, or `NUMERIC(x,y)`. For example, 8-byte types first (`BIGINT`, `TIMESTAMP`), 4-byte types next (`INT`, `DATE`), 2-byte types next (`SMALLINT`), and variable data type last (`VARCHAR`).

Instead of defining columns in this sequence:

`Int`, `Bigint`, `Timestamp`, `Bigint`, `Timestamp`, `Int` (distribution key), `Date` (partition key), `Bigint`, `Smallint`

define the columns in this sequence:

`Int` (distribution key), `Date` (partition key), `Bigint`, `Bigint`, `Timestamp`, `Bigint`, `Timestamp`, `Int`, `Smallint`

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6.4 Memory and Resource Management with Resource Groups

Managing WarehousePG resources with resource groups.

Memory, CPU, and concurrent transaction management have a significant impact on performance in a WarehousePG cluster. Resource groups are a newer resource management scheme that enforce memory, CPU, and concurrent transaction limits in WarehousePG.

- Configuring Memory for WarehousePG
- Memory Considerations when using Resource Groups
- Configuring Resource Groups
- Low Memory Queries
- Administrative Utilities and admin_group Concurrency

Configuring Memory for WarehousePG

While it is not always possible to increase system memory, you can avoid many out-of-memory conditions by configuring resource groups to manage expected workloads.

The following operating system and WarehousePG memory settings are significant when you manage WarehousePG resources with resource groups:

- **vm.overcommit_memory**

  This Linux kernel parameter, set in `/etc/sysctl.conf`, identifies the method that the operating system uses to determine how much memory can be allocated to processes. `vm.overcommit_memory` must always be set to 2 for WarehousePG clusters.

- **vm.overcommit_ratio**

  This Linux kernel parameter, set in `/etc/sysctl.conf`, identifies the percentage of RAM that is used for application processes; the remainder is reserved for the operating system. Tune the setting as necessary. If your memory utilization is too low, increase the value; if your memory or swap usage is too high, decrease the setting.

- **gp_workfile_limit_files_per_query**

  Set `gp_workfile_limit_files_per_query` to limit the maximum number of temporary spill files (workfiles) allowed per query. Spill files are created when a query requires more memory than it is allocated. When the limit is exceeded the query is terminated. The default is zero, which allows an unlimited number of spill files and may fill up the file system.

- **gp_workfile_compression**

  If there are numerous spill files then set `gp_workfile_compression` to compress the spill files. Compressing spill files may help to avoid overloading the disk subsystem with IO operations.

- **statement_mem**

  WarehousePG uses the `statement_mem` setting to determine the amount of memory to allocate to a query.

Other considerations:

- Do not configure the operating system to use huge pages. See the Recommended OS Parameters Settings in the *WarehousePG Installation Guide*.
- When you configure resource group memory, consider memory requirements for mirror segments that become primary segments during a failure to ensure that database operations can continue when primary segments or segment hosts fail.

Memory Considerations when using Resource Groups

Available memory for resource groups may be limited on systems that use low or no swap space, and that use the default `vm.overcommit_ratio`. To ensure that WarehousePG has a reasonable per-segment-host memory limit, you may be required to increase one or more of the following configuration settings:

1. The swap size on the system.
2. The system's `vm.overcommit_ratio` setting.

Configuring Resource Groups

WarehousePG resource groups provide a powerful mechanism for managing the workload of the cluster. Consider these general guidelines when you configure resource groups for your system:

- A transaction submitted by any WarehousePG role with `SUPERUSER` privileges runs under the default resource group named `admin_group`. Keep this in mind when scheduling and running WarehousePG administration utilities.
- Ensure that you assign each non-admin role a resource group. If you do not assign a resource group to a role, queries submitted by the role are handled by the default resource group named `default_group`.
- Use the `CONCURRENCY` resource group parameter to limit the number of active queries that members of a particular resource group can run concurrently.
- Use the `MEMORY_QUOTA` parameter to control the maximum amount of memory that queries running in the resource group can consume.
- WarehousePG assigns unreserved memory (100 - (sum of all resource group `MEMORY_QUOTA`s) to a global shared memory pool. This memory is available to all queries on a first-come, first-served basis.
- Alter resource groups dynamically to match the real requirements of the group for the workload and the time of day.
- Use the `gp_toolkit` views to examine resource group resource usage and to monitor how the groups are working.

Low Memory Queries

A low `statement_mem` setting (for example, in the 10MB range) has been shown to increase the performance of queries with low memory requirements. Use the `statement_mem` server configuration parameter to override the setting on a per-query basis. For example:

```
SET statement_mem='10 MB';
```

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Administrative Utilities and admin_group Concurrency

The default resource group for database transactions initiated by WarehousePG `SUPERUSER` s is the group named `admin_group`. The default `CONCURRENCY` value for the `admin_group` resource group is 10.

Certain WarehousePG administrative utilities may use more than one `CONCURRENCY` slot at runtime, such as `gpbackup` that you invoke with the `--jobs` option. If the utility(s) you run require more concurrent transactions than that configured for `admin_group`, consider temporarily increasing the group's `MEMORY_QUOTA` and `CONCURRENCY` values to meet the utility's requirement, making sure to return these parameters back to their original settings when the utility completes.

> **Note** Memory allocation changes that you initiate with `ALTER RESOURCE GROUP` may not take affect immediately due to resource consumption by currently running queries. Be sure to alter resource group parameters in advance of your maintenance window.

Parent topic: WarehousePG Best Practices

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6.5 Memory and Resource Management with Resource Queues

Avoid memory errors and manage WarehousePG resources.

> **Note** Resource groups are a newer resource management scheme that enforces memory, CPU, and concurrent transaction limits in WarehousePG. TheManaging Resources topic provides a comparison of the resource queue and the resource group management schemes. Refer to Using Resource Groups for configuration and usage information for this resource management scheme.

Memory management has a significant impact on performance in a WarehousePG cluster. The default settings are suitable for most environments. Do not change the default settings until you understand the memory characteristics and usage on your system.

- Resolving Out of Memory Errors
- Low Memory Queries
- Configuring Memory for WarehousePG
- Configuring Resource Queues

Resolving Out of Memory Errors

An out of memory error message identifies the WarehousePG segment, host, and process that experienced the out of memory error. For example:

```
Out of memory (seg27 host.example.com pid=47093)
VM Protect failed to allocate 4096 bytes, 0 MB available
```

Some common causes of out-of-memory conditions in WarehousePG are:

- Insufficient system memory (RAM) available on the cluster
- Improperly configured memory parameters
- Data skew at the segment level
- Operational skew at the query level

Following are possible solutions to out of memory conditions:

- Tune the query to require less memory
- Reduce query concurrency using a resource queue
- Validate the `gp_vmem_protect_limit` configuration parameter at the database level. See calculations for the maximum safe setting in Configuring Memory for WarehousePG.
- Set the memory quota on a resource queue to limit the memory used by queries run within the resource queue
- Use a session setting to reduce the `statement_mem` used by specific queries
- Decrease `statement_mem` at the database level
- Decrease the number of segments per host in the WarehousePG cluster. This solution requires a re-initializing WarehousePG and reloading your data.
- Increase memory on the host, if possible. (Additional hardware may be required.)

Adding segment hosts to the cluster will not in itself alleviate out of memory problems. The memory used by each query is determined by the `statement_mem` parameter and it is set when the query is invoked. However, if adding more hosts allows decreasing the number of segments per host, then the amount of memory allocated in `gp_vmem_protect_limit` can be raised.

Low Memory Queries

A low `statement_mem` setting (for example, in the 1-3MB range) has been shown to increase the performance of queries with low memory requirements. Use the `statement_mem` server configuration parameter to override the setting on a per-query basis. For example:

```
SET statement_mem='2MB';
```

Configuring Memory for WarehousePG

Most out of memory conditions can be avoided if memory is thoughtfully managed.

It is not always possible to increase system memory, but you can prevent out-of-memory conditions by configuring memory use correctly and setting up resource queues to manage expected workloads.

It is important to include memory requirements for mirror segments that become primary segments during a failure to ensure that the cluster can continue when primary segments or segment hosts fail.

The following are recommended operating system and WarehousePG memory settings:

- Do not configure the OS to use huge pages.
- **vm.overcommit_memory**

  This is a Linux kernel parameter, set in `/etc/sysctl.conf` and it should always be set to 2. It determines the method the OS uses for determining how much memory can be allocated to processes and 2 is the only safe setting for WarehousePG. Please review the sysctl parameters in the WarehousePG Installation Guide.
- **vm.overcommit_ratio**

  This is a Linux kernel parameter, set in `/etc/sysctl.conf`. It is the percentage of RAM that is used for application processes. The remainder is reserved for the operating system. The default on Red Hat is 50.

  Setting `vm.overcommit_ratio` too high may result in not enough memory being reserved for the operating system, which can result in segment host failure or database failure. Setting the value too low reduces the amount of concurrency and query complexity that can be run by reducing the amount of memory available to WarehousePG. When increasing the setting it is important to remember to always reserve some memory for operating system activities.

  See WarehousePG Memory Overview for instructions to calculate a value for `vm.overcommit_ratio`.

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- **gp_vmem_protect_limit**

  Use `gp_vmem_protect_limit` to set the maximum memory that the instance can allocate for *all* work being done in each segment database. Never set this value larger than the physical RAM on the system. If `gp_vmem_protect_limit` is too high, it is possible for memory to become exhausted on the system and normal operations may fail, causing segment failures. If `gp_vmem_protect_limit` is set to a safe lower value, true memory exhaustion on the system is prevented; queries may fail for hitting the limit, but system disruption and segment failures are avoided, which is the desired behavior.

  See Resource Queue Segment Memory Configuration for instructions to calculate a safe value for `gp_vmem_protect_limit`.

- **runaway_detector_activation_percent**

  Runaway Query Termination, prevents out of memory conditions. The `runaway_detector_activation_percent` system parameter controls the percentage of `gp_vmem_protect_limit` memory utilized that triggers termination of queries. It is set on by default at 90%. If the percentage of `gp_vmem_protect_limit` memory that is utilized for a segment exceeds the specified value, WarehousePG terminates queries based on memory usage, beginning with the query consuming the largest amount of memory. Queries are terminated until the utilized percentage of `gp_vmem_protect_limit` is below the specified percentage.

- **statement_mem**

  Use `statement_mem` to allocate memory used for a query per segment database. If additional memory is required it will spill to disk. Set the optimal value for `statement_mem` as follows:

  ```
  (vmprotect * .9) / max_expected_concurrent_queries
  ```

  The default value of `statement_mem` is 125MB. For example, on a system that is configured with 8 segments per host, a query uses 1GB of memory on each segment server (8 segments ⨉ 125MB) with the default `statement_mem` setting. Set `statement_mem` at the session level for specific queries that require additional memory to complete. This setting works well to manage query memory on clusters with low concurrency. For clusters with high concurrency also use resource queues to provide additional control on what and how much is running on the system.

- **gp_workfile_limit_files_per_query**

  Set `gp_workfile_limit_files_per_query` to limit the maximum number of temporary spill files (workfiles) allowed per query. Spill files are created when a query requires more memory than it is allocated. When the limit is exceeded the query is terminated. The default is zero, which allows an unlimited number of spill files and may fill up the file system.

- **gp_workfile_compression**

  If there are numerous spill files then set `gp_workfile_compression` to compress the spill files. Compressing spill files may help to avoid overloading the disk subsystem with IO operations.

Configuring Resource Queues

WarehousePG resource queues provide a powerful mechanism for managing the workload of the cluster. Queues can be used to limit both the numbers of active queries and the amount of memory that can be used by queries in the queue. When a query is submitted to WarehousePG, it is added to a resource queue, which determines if the query should be accepted and when the resources are available to run it.

- Associate all roles with an administrator-defined resource queue.

  Each login user (role) is associated with a single resource queue; any query the user submits is handled by the associated resource queue. If a queue is not explicitly assigned the user's queries are handed by the default queue, `pg_default`.

- Do not run queries with the gpadmin role or other superuser roles.

  Superusers are exempt from resource queue limits, therefore superuser queries always run regardless of the limits set on their assigned queue.

- Use the `ACTIVE_STATEMENTS` resource queue parameter to limit the number of active queries that members of a particular queue can run concurrently.

- Use the `MEMORY_LIMIT` parameter to control the total amount of memory that queries running through the queue can utilize. By combining the `ACTIVE_STATEMENTS` and `MEMORY_LIMIT` attributes an administrator can fully control the activity emitted from a given resource queue.

  The allocation works as follows: Suppose a resource queue, `sample_queue`, has `ACTIVE_STATEMENTS` set to 10 and `MEMORY_LIMIT` set to 2000MB. This limits the queue to approximately 2 gigabytes of memory per segment. For a cluster with 8 segments per server, the total usage per server is 16 GB for `sample_queue` (2GB * 8 segments/server). If a segment server has 64GB of RAM, there could be no more than four of this type of resource queue on the system before there is a chance of running out of memory (4 queues * 16GB per queue).

  Note that by using `STATEMENT_MEM`, individual queries running in the queue can allocate more than their "share" of memory, thus reducing the memory available for other queries in the queue.

- Resource queue priorities can be used to align workloads with desired outcomes. Queues with `MAX` priority throttle activity in all other queues until the `MAX` queue completes running all queries.

- Alter resource queues dynamically to match the real requirements of the queue for the workload and time of day. You can script an operational flow that changes based on the time of day and type of usage of the system and add `crontab` entries to run the scripts.

- Use gptoolkit to view resource queue usage and to understand how the queues are working.

Parent topic: WarehousePG Best Practices

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6.6 System Monitoring and Maintenance

Best practices for regular maintenance that will ensure WarehousePG high availability and optimal performance.

- Updating Statistics with ANALYZE
- Managing Bloat in a Database
- Monitoring WarehousePG Log Files

Parent topic: WarehousePG Best Practices

Monitoring

WarehousePG includes utilities that are useful for monitoring the system.

The `gp_toolkit` schema contains several views that can be accessed using SQL commands to query system catalogs, log files, and operating environment for system status information.

The `gp_stats_missing` view shows tables that do not have statistics and require `ANALYZE` to be run.

For additional information on `gpstate` and `gpcheckperf` refer to the *WarehousePG Utility Guide*. For information about the `gp_toolkit` schema, see the *WarehousePG Reference Guide*.

gpstate

The `gpstate` utility program displays the status of the WarehousePG cluster, including which segments are down, coordinator and segment configuration information (hosts, data directories, etc.), the ports used by the system, and mapping of primary segments to their corresponding mirror segments.

Run `gpstate -Q` to get a list of segments that are marked "down" in the coordinator system catalog.

To get detailed status information for the WarehousePG cluster, run `gpstate -s`.

gpcheckperf

The `gpcheckperf` utility tests baseline hardware performance for a list of hosts. The results can help identify hardware issues. It performs the following checks:

- disk I/O test – measures I/O performance by writing and reading a large file using the `dd` operating system command. It reports read and write rates in megabytes per second.
- memory bandwidth test – measures sustainable memory bandwidth in megabytes per second using the STREAM benchmark.
- network performance test – runs the `gpnetbench` network benchmark program (optionally `netperf)` to test network performance. The test is run in one of three modes: parallel pair test (`-r N`), serial pair test (`-r n`), or full-matrix test (`-r M)` . The minimum, maximum, average, and median transfer rates are reported in megabytes per second.

To obtain valid numbers from `gpcheckperf`, the database system must be stopped. The numbers from `gpcheckperf` can be inaccurate even if the system is up and running with no query activity.

`gpcheckperf` requires a trusted host setup between the hosts involved in the performance test. It calls `gpssh` and `gpsync`, so these utilities must also be in your `PATH`. Specify the hosts to check individually (`-h *host1* -h *host2* ...`) or with `-f *hosts_file*`, where `*hosts_file*` is a text file containing a list of the hosts to check. If you have more than one subnet, create a separate host file for each subnet so that you can test the subnets separately.

By default, `gpcheckperf` runs the disk I/O test, the memory test, and a serial pair network performance test. With the disk I/O test, you must use the `-d` option to specify the file systems you want to test. The following command tests disk I/O and memory bandwidth on hosts listed in the `subnet_1_hosts` file:

```
$ gpcheckperf -f subnet_1_hosts -d /data1 -d /data2 -r ds
```

The `-r` option selects the tests to run: disk I/O (`d`), memory bandwidth (`s`), network parallel pair (`N`), network serial pair test (`n`), network full-matrix test (`M`). Only one network mode can be selected per execution. See the *WarehousePG Reference Guide* for the detailed `gpcheckperf` reference.

Monitoring with Operating System Utilities

The following Linux/UNIX utilities can be used to assess host performance:

- `iostat` allows you to monitor disk activity on segment hosts.
- `top` displays a dynamic view of operating system processes.
- `vmstat` displays memory usage statistics.

You can use `gpssh` to run utilities on multiple hosts.

Best Practices

- Implement the "Recommended Monitoring and Maintenance Tasks" in the *WarehousePG Administrator Guide*.
- Run `gpcheckperf` at install time and periodically thereafter, saving the output to compare system performance over time.
- Use all the tools at your disposal to understand how your system behaves under different loads.
- Examine any unusual event to determine the cause.
- Monitor query activity on the system by running explain plans periodically to ensure the queries are running optimally.
- Review plans to determine whether index are being used and partition elimination is occurring as expected.

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Additional Information

- `gpcheckperf` reference in the *WarehousePG Utility Guide*.
- "Recommended Monitoring and Maintenance Tasks" in the *WarehousePG Administrator Guide*.
- Sustainable Memory Bandwidth in Current High Performance Computers. John D. McCalpin. Oct 12, 1995.
- www.netperf.org to use `netperf`, netperf must be installed on each host you test. See `gpcheckperf` reference for more information.

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6.6.1 Updating Statistics with ANALYZE

The most important prerequisite for good query performance is to begin with accurate statistics for the tables. Updating statistics with the `ANALYZE` statement enables the query planner to generate optimal query plans. When a table is analyzed, information about the data is stored in the system catalog tables. If the stored information is out of date, the planner can generate inefficient plans.

Generating Statistics Selectively

Running ANALYZE with no arguments updates statistics for all tables in the database. This can be a very long-running process and it is not recommended. You should `ANALYZE` tables selectively when data has changed or use the analyzedb utility.

Running `ANALYZE` on a large table can take a long time. If it is not feasible to run `ANALYZE` on all columns of a very large table, you can generate statistics for selected columns only using `ANALYZE table(column, ...)`. Be sure to include columns used in joins, `WHERE` clauses, `SORT` clauses, `GROUP BY` clauses, or `HAVING` clauses.

For a partitioned table, you can run `ANALYZE` just on partitions that have changed, for example, if you add a new partition. Note that for partitioned tables, you can run `ANALYZE` on the root partitioned table, or on the leaf partitions (files where data and statistics are actually stored). The intermediate files for sub-partitioned tables store no data or statistics, so running `ANALYZE` on them does not work. You can find the names of the leaf partitions using the `pg_partition_tree()` function:

```
SELECT * FROM pg_partition_tree( 'parent_table' );
```

Improving Statistics Quality

There is a trade-off between the amount of time it takes to generate statistics and the quality, or accuracy, of the statistics.

To allow large tables to be analyzed in a reasonable amount of time, `ANALYZE` takes a random sample of the table contents, rather than examining every row. To increase the number of sample values for all table columns adjust the `default_statistics_target` configuration parameter. The target value ranges from 1 to 1000; the default target value is 100. The `default_statistics_target` variable applies to all columns by default, and specifies the number of values that are stored in the list of common values. A larger target may improve the quality of the query planner's estimates, especially for columns with irregular data patterns. `default_statistics_target` can be set at the coordinator/session level and requires a reload.

When to Run ANALYZE

Run `ANALYZE`:

- after loading data,
- after `CREATE INDEX` operations,
- and after `INSERT`, `UPDATE`, and `DELETE` operations that significantly change the underlying data.

`ANALYZE` requires only a read lock on the table, so it may be run in parallel with other database activity, but do not run `ANALYZE` while performing loads, `INSERT`, `UPDATE`, `DELETE`, and `CREATE INDEX` operations.

Configuring Automatic Statistics Collection

The `gp_autostats_mode` configuration parameter, together with the `gp_autostats_on_change_threshold` parameter, determines when an automatic analyze operation is triggered. When automatic statistics collection is triggered, the planner adds an `ANALYZE` step to the query.

By default, `gp_autostats_mode` is `on_no_stats`, which triggers statistics collection for `CREATE TABLE AS SELECT`, `INSERT`, or `COPY` operations invoked by the table owner on any table that has no existing statistics.

Setting `gp_autostats_mode` to `on_change` triggers statistics collection only when the number of rows affected exceeds the threshold defined by `gp_autostats_on_change_threshold`, which has a default value of 2147483647. The following operations invoked on a table by its owner can trigger automatic statistics collection with `on_change`: `CREATE TABLE AS SELECT`, `UPDATE`, `DELETE`, `INSERT`, and `COPY`.

Setting the `gp_autostats_allow_nonowner` server configuration parameter to `true` also instructs WarehousePG to trigger automatic statistics collection on a table when:

- `gp_autostats_mode=on_change` and the table is modified by a non-owner.
- `gp_autostats_mode=on_no_stats` and the first user to `INSERT` or `COPY` into the table is a non-owner.

Setting `gp_autostats_mode` to `none` deactivates automatics statistics collection.

For partitioned tables, automatic statistics collection is not triggered if data is inserted from the top-level parent table of a partitioned table. But automatic statistics collection *is* triggered if data is inserted directly in a leaf table (where the data is stored) of the partitioned table.

Parent topic: System Monitoring and Maintenance

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6.6.2 Managing Bloat in a Database

Database bloat occurs in heap tables, append-optimized tables, indexes, and system catalogs and affects database performance and disk usage. You can detect database bloat and remove it from the database.

- About Bloat
- Detecting Bloat
- Removing Bloat from Database Tables
- Removing Bloat from Append-Optimized Tables
- Removing Bloat from Indexes
- Removing Bloat from System Catalogs

About Bloat

Database bloat is disk space that was used by a table or index and is available for reuse by the database but has not been reclaimed. Bloat is created when updating tables or indexes.

Because WarehousePG heap tables use the PostgreSQL Multiversion Concurrency Control (MVCC) storage implementation, a deleted or updated row is logically deleted from the database, but a non-visible image of the row remains in the table. Moreover, if the table has an index, index entries to these non-visible rows also remain. Running `VACUUM` marks the expired rows as free space that is available for reuse by subsequent inserts, and removes the corresponding index entries if any exist.

It is normal for tables that have frequent updates to have a small or moderate amount of expired rows and free space that will be reused as new data is added. But when the table is allowed to grow so large that active data occupies just a small fraction of the space, the table has become significantly bloated. Bloated tables require more disk storage and additional I/O that can slow down query execution. It can also slow down data ingest if a bloated table has a unique index, as uniqueness validation checks will read the aforementioned index entries.

> **Important** It is very important to run `VACUUM` on individual tables after large `UPDATE` and `DELETE` operations to avoid the necessity of ever running `VACUUM FULL`.

Running the `VACUUM` command regularly on tables prevents them from growing too large. If the table does become significantly bloated, the `VACUUM FULL` command must be used to compact the table data.

If the free space map is not large enough to accommodate all of the expired rows, the `VACUUM` command is unable to reclaim space for expired rows that overflowed the free space map. The disk space may only be recovered by running `VACUUM FULL`, which locks the table, creates a new table, copies the table data to the new table, and then drops old table. This is an expensive operation that can take an exceptional amount of time to complete with a large table.

> **Caution** `VACUUM FULL` acquires an `ACCESS EXCLUSIVE` lock on tables. You should not run `VACUUM FULL`. If you run `VACUUM FULL` on tables, run it during a time when users and applications do not require access to the tables, such as during a time of low activity, or during a maintenance window.

Detecting Bloat

The statistics collected by the `ANALYZE` statement can be used to calculate the expected number of disk pages required to store a table. The difference between the expected number of pages and the actual number of pages is a measure of bloat. The `gp_toolkit` schema provides the gp_bloat_diag view that identifies table bloat by comparing the ratio of expected to actual pages. To use it, make sure statistics are up to date for all of the tables in the database, then run the following SQL:

```
gpadmin=# SELECT * FROM gp_toolkit.gp_bloat_diag;
 bdirelid | bdinspname | bdirelname | bdirelpages | bdiexppages |                bdidiag
----------+------------+------------+-------------+-------------+----------------------------------------
    21488 | public     | t1         |          97 |           1 | significant amount of bloat suspected
(1 row)
```

The results include only tables with moderate or significant bloat. Moderate bloat is reported when the ratio of actual to expected pages is greater than four and less than ten. Significant bloat is reported when the ratio is greater than ten.

The `gp_toolkit.gp_bloat_expected_pages` view lists the actual number of used pages and expected number of used pages for each database object.

```
gpadmin=# SELECT * FROM gp_toolkit.gp_bloat_expected_pages LIMIT 5;
 btdrelid | btdrelpages | btdexppages
----------+-------------+-------------
    10789 |           1 |           1
    10794 |           1 |           1
    10799 |           1 |           1
     5004 |           1 |           1
     7175 |           1 |           1
(5 rows)
```

The `btdrelid` is the object ID of the table. The `btdrelpages` column reports the number of pages the table uses; the `btdexppages` column is the number of pages expected. Again, the numbers reported are based on the table statistics, so be sure to run `ANALYZE` on tables that have changed.

Removing Bloat from Database Tables

The `VACUUM` command adds expired rows to the free space map so that the space can be reused. When `VACUUM` is run regularly on a table that is frequently updated, the space occupied by the expired rows can be promptly reused, preventing the table file from growing larger. It is also important to run `VACUUM` before the free space map is filled. For heavily updated tables, you may need to run `VACUUM` at least once a day to prevent the table from becoming bloated.

> **Caution** When a table is significantly bloated, it is better to run `VACUUM` before running `ANALYZE`. Analyzing a severely bloated table can generate poor statistics if the sample contains empty pages, so it is good practice to vacuum a bloated table before analyzing it.

When a table accumulates significant bloat, running the `VACUUM` command is insufficient. For small tables, running `VACUUM FULL <table_name>` can reclaim space used by rows that overflowed the free space map and reduce the size of the table file. However, a `VACUUM FULL` statement is an expensive operation that requires an `ACCESS EXCLUSIVE` lock and may take an exceptionally long and unpredictable amount of time to finish for large tables. You should run `VACUUM FULL` on tables during a time when users and applications do not require access to the tables being vacuumed, such as during a time of low activity, or during a maintenance window.

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Removing Bloat from Append-Optimized Tables

Append-optimized tables are handled much differently than heap tables. Although append-optimized tables allow update, insert, and delete operations, these operations are not optimized and are not recommended with append-optimized tables. If you heed this advice and use append-optimized for *load-once/read-many* workloads, `VACUUM` on an append-optimized table runs almost instantaneously.

If you do run `UPDATE` or `DELETE` commands on an append-optimized table, expired rows are tracked in an auxiliary bitmap instead of the free space map. `VACUUM` is the only way to recover the space. Running `VACUUM` on an append-optimized table with expired rows compacts a table by rewriting the entire table without the expired rows. However, no action is performed if the percentage of expired rows in the table exceeds the value of the `gp_appendonly_compaction_threshold` configuration parameter, which is 10 (10%) by default. The threshold is checked on each segment, so it is possible that a `VACUUM` statement will compact an append-only table on some segments and not others. Compacting append-only tables can be deactivated by setting the `gp_appendonly_compaction` parameter to `no`.

Removing Bloat from Indexes

The `VACUUM` command only recovers space from tables. To recover the space from indexes, recreate them using the `REINDEX` command.

To rebuild all indexes on a table run `REINDEX *table_name*;`. To rebuild a particular index, run `REINDEX *index_name*;`. `REINDEX` sets the `reltuples` and `relpages` to 0 (zero) for the index, To update those statistics, run `ANALYZE` on the table after reindexing.

Removing Bloat from System Catalogs

WarehousePG cluster catalog tables are heap tables and can become bloated over time. As database objects are created, altered, or dropped, expired rows are left in the system catalogs. Using `gpload` to load data contributes to the bloat since `gpload` creates and drops external tables. (Rather than use `gpload`, it is recommended to use `gpfdist` to load data.)

Bloat in the system catalogs increases the time require to scan the tables, for example, when creating explain plans. System catalogs are scanned frequently and if they become bloated, overall system performance is degraded.

It is recommended to run `VACUUM` on system catalog tables nightly and at least weekly. At the same time, running `REINDEX SYSTEM` on system catalog tables removes bloat from the indexes. Alternatively, you can reindex system tables using the `reindexdb` utility with the `-s` (`--system`) option. After removing catalog bloat, run `ANALYZE` to update catalog table statistics.

These are WarehousePG cluster catalog maintenance steps.

1. Perform a `REINDEX` on the system catalog tables to rebuild the system catalog indexes. This removes bloat in the indexes and improves `VACUUM` performance.

   > **Note** When performing `REINDEX` on the system catalog tables, locking will occur on the tables and might have an impact on currently running queries. You can schedule the `REINDEX` operation during a period of low activity to avoid disrupting ongoing business operations.

2. Perform a `VACUUM` on system catalog tables.

3. Perform an `ANALYZE` on the system catalog tables to update the table statistics.

If you are performing system catalog maintenance during a maintenance period and you need to stop a process due to time constraints, run the WarehousePG function `pg_cancel_backend(<PID>)` to safely stop a WarehousePG process.

The following script runs `REINDEX`, `VACUUM`, and `ANALYZE` on the system catalogs.

```
#!/bin/bash
DBNAME="<database_name>"
SYSTABLES="' pg_catalog.' || relname || ';' from pg_class a, pg_namespace b \
where a.relnamespace=b.oid and b.nspname='pg_catalog' and a.relkind='r'"

reindexdb -s -d $DBNAME
psql -tc "SELECT 'VACUUM' || $SYSTABLES" $DBNAME | psql -a $DBNAME
analyzedb -a -s pg_catalog -d $DBNAME
```

If the system catalogs become significantly bloated, you must run `VACUUM FULL` during a scheduled downtime period. During this period, stop all catalog activity on the system; `VACUUM FULL` takes `ACCESS EXCLUSIVE` locks against the system catalog. Running `VACUUM` regularly on system catalog tables can prevent the need for this more costly procedure.

These are steps for intensive system catalog maintenance.

1. Stop all catalog activity on the WarehousePG cluster.
2. Perform a `VACUUM FULL` on the system catalog tables. See the following Note.
3. Perform an `ANALYZE` on the system catalog tables to update the catalog table statistics.

> **Note** The system catalog table `pg_attribute` is usually the largest catalog table. If the `pg_attribute` table is significantly bloated, a `VACUUM FULL` operation on the table might require a significant amount of time and might need to be performed separately. The presence of both of these conditions indicate a significantly bloated `pg_attribute` table that might require a long `VACUUM FULL` time:

- The `pg_attribute` table contains a large number of records.
- The diagnostic message for `pg_attribute` is `significant amount of bloat` in the `gp_toolkit.gp_bloat_diag` view.

Parent topic: System Monitoring and Maintenance

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6.6.3 Monitoring WarehousePG Log Files

Know the location and content of system log files and monitor them on a regular basis and not just when problems arise.

The following table shows the locations of the various WarehousePG log files. In file paths:

- `$GPADMIN_HOME` refers to the home directory of the `gpadmin` operating system user.
- `$COORDINATOR_DATA_DIRECTORY` refers to the coordinator data directory on the WarehousePG coordinator host.
- `$GPDATA_DIR` refers to a data directory on the WarehousePG segment host.
- `host` identifies the WarehousePG segment host name.
- `segprefix` identifies the segment prefix.
- `N` identifies the segment instance number.
- `date` is a date in the format `YYYYMMDD`.

Path	Description
`$GPADMIN_HOME/gpAdminLogs/*`	Many different types of log files, directory on each server. `$GPADMIN_HOME` is the default location for the `gpAdminLogs/` directory. You can specify a different location when you run an administrative utility command.
`$GPADMIN_HOME/gpAdminLogs/gpinitsystem_date.log`	system initialization log
`$GPADMIN_HOME/gpAdminLogs/gpstart_date.log`	start log
`$GPADMIN_HOME/gpAdminLogs/gpstop_date.log`	stop log
`$GPADMIN_HOME/gpAdminLogs/gpsegstart.py_host:gpadmin_date.log`	segment host start log
`$GPADMIN_HOME/gpAdminLogs/gpsegstop.py_host:gpadmin_date.log`	segment host stop log
`$COORDINATOR_DATA_DIRECTORY/log/startup.log`, `$GPDATA_DIR/segprefixN/log/startup.log`	segment instance start log
`$COORDINATOR_DATA_DIRECTORY/log/*.csv`, `$GPDATA_DIR/segprefixN/log/*.csv`	coordinator and segment database logs
`$GPDATA_DIR/mirror/segprefixN/log/*.csv`	mirror segment database logs
`$GPDATA_DIR/primary/segprefixN/log/*.csv`	primary segment database logs
`/var/log/messages`	Global Linux system messages

> **Note** If you manually set the server configuration parameter log_directory to specify a different directory for log files, the items on the table above whose path is under `$COORDINATOR_DATA_DIRECTORY` or `$GPDATA_DIR` should point to the value of `log_directory` instead. Note that when you specify the value as an absolute path, or as a relative path that is outside the data directory, WarehousePG appends a subdirectory with a unique identifier (DBID) to the directory specified by this parameter. The unique identifier matches the value of `dbid` from `gp_segment_configuration`. For example, if you set `log_directory` as `/tmp/logs`, WarehousePG creates the directories: `/tmp/logs/1` for the coordinator, `/tmp/logs/2` for seg0, `/tmp/logs/3` for seg1, etcetera.

Use `gplogfilter -t` (`--trouble`) first to search the coordinator log for messages beginning with `ERROR:`, `FATAL:`, or `PANIC:`. Messages beginning with `WARNING` may also provide useful information.

To search log files on the segment hosts, use the WarehousePG `gplogfilter` utility with `gpssh` to connect to segment hosts from the coordinator host. You can identify corresponding log entries in segment logs by the `statement_id`.

WarehousePG can be configured to rotate database logs based on the size and/or age of the current log file. The `log_rotation_size` configuration parameter sets the size of an individual log file that triggers rotation. When the current log file size is equal to or greater than this size, the file is closed and a new log file is created. The `log_rotation_age` configuration parameter specifies the age of the current log file that triggers rotation. When the specified time has elapsed since the current log file was created, a new log file is created. The default `log_rotation_age`, `1d`, creates a new log file 24 hours after the current log file was created.

Parent topic: System Monitoring and Maintenance

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6.7 Loading Data

Description of the different ways to add data to WarehousePG.

Parent topic: WarehousePG Best Practices

INSERT Statement with Column Values

A singleton `INSERT` statement with values adds a single row to a table. The row flows through the coordinator and is distributed to a segment. This is the slowest method and is not suitable for loading large amounts of data.

COPY Statement

The PostgreSQL `COPY` statement copies data from an external file into a database table. It can insert multiple rows more efficiently than an `INSERT` statement, but the rows are still passed through the coordinator. All of the data is copied in one command; it is not a parallel process.

Data input to the `COPY` command is from a file or the standard input. For example:

```
COPY table FROM '/data/mydata.csv' WITH CSV HEADER;
```

Use `COPY` to add relatively small sets of data, for example dimension tables with up to ten thousand rows, or one-time data loads.

Use `COPY` when scripting a process that loads small amounts of data, less than 10 thousand rows.

Since COPY is a single command, there is no need to deactivate autocommit when you use this method to populate a table.

You can run multiple concurrent `COPY` commands to improve performance.

External Tables

External tables provide access to data in sources outside of WarehousePG. They can be accessed with `SELECT` statements and are commonly used with the Extract, Load, Transform (ELT) pattern, a variant of the Extract, Transform, Load (ETL) pattern that takes advantage of WarehousePG's fast parallel data loading capability.

With ETL, data is extracted from its source, transformed outside of the database using external transformation tools, such as Datastage, and then loaded into the database.

With ELT, WarehousePG external tables provide access to data in external sources, which could be read-only files (for example, text, CSV, or XML files), Web servers, Hadoop file systems, executable OS programs, or the WarehousePG `gpfdist` file server, described in the next section. External tables support SQL operations such as select, sort, and join so the data can be loaded and transformed simultaneously, or loaded into a*load table* and transformed in the database into target tables.

The external table is defined with a `CREATE EXTERNAL TABLE` statement, which has a `LOCATION` clause to define the location of the data and a `FORMAT` clause to define the formatting of the source data so that the system can parse the input data. Files use the `file://` protocol, and must reside on a segment host in a location accessible by the WarehousePG superuser. The data can be spread out among the segment hosts with no more than one file per primary segment on each host. The number of files listed in the `LOCATION` clause is the number of segments that will read the external table in parallel.

External Tables with Gpfdist

The fastest way to load large fact tables is to use external tables with `gpfdist`. `gpfdist` is a file server program using an HTTP protocol that serves external data files to WarehousePG segments in parallel. A `gpfdist` instance can serve 200 MB/second and many `gpfdist` processes can run simultaneously, each serving up a portion of the data to be loaded. When you begin the load using a statement such as `INSERT INTO <table> SELECT * FROM <external_table>`, the `INSERT` statement is parsed by the coordinator and distributed to the primary segments. The segments connect to the `gpfdist` servers and retrieve the data in parallel, parse and validate the data, calculate a hash from the distribution key data and, based on the hash key, send the row to its destination segment. By default, each `gpfdist` instance will accept up to 64 connections from segments. With many segments and `gpfdist` servers participating in the load, data can be loaded at very high rates.

Primary segments access external files in parallel when using `gpfdist` up to the value of `gp_external_max_segs`. When optimizing `gpfdist` performance, maximize the parallelism as the number of segments increase. Spread the data evenly across as many ETL nodes as possible. Split very large data files into equal parts and spread the data across as many file systems as possible.

Run two `gpfdist` instances per file system. `gpfdist` tends to be CPU bound on the segment nodes when loading. But if, for example, there are eight racks of segment nodes, there is lot of available CPU on the segments to drive more `gpfdist` processes. Run `gpfdist` on as many interfaces as possible. Be aware of bonded NICs and be sure to start enough `gpfdist` instances to work them.

It is important to keep the work even across all these resources. The load is as fast as the slowest node. Skew in the load file layout will cause the overall load to bottleneck on that resource.

The `gp_external_max_segs` configuration parameter controls the number of segments each `gpfdist` process serves. The default is 64. You can set a different value in the `postgresql.conf` configuration file on the coordinator. Always keep `gp_external_max_segs` and the number of `gpfdist` processes an even factor; that is, the `gp_external_max_segs` value should be a multiple of the number of `gpfdist` processes. For example, if there are 12 segments and 4 `gpfdist` processes, the planner round robins the segment connections as follows:

```
Segment 1  - gpfdist 1
Segment 2  - gpfdist 2
Segment 3  - gpfdist 3
Segment 4  - gpfdist 4
Segment 5  - gpfdist 1
Segment 6  - gpfdist 2
Segment 7  - gpfdist 3
Segment 8  - gpfdist 4
Segment 9  - gpfdist 1
Segment 10 - gpfdist 2
Segment 11 - gpfdist 3
Segment 12 - gpfdist 4
```

Drop indexes before loading into existing tables and re-create the index after loading. Creating an index on pre-existing data is faster than updating it incrementally as each row is loaded.

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Run `ANALYZE` on the table after loading. Deactivate automatic statistics collection during loading by setting `gp_autostats_mode` to `NONE`. Run `VACUUM` after load errors to recover space.

Performing small, high frequency data loads into heavily partitioned column-oriented tables can have a high impact on the system because of the number of physical files accessed per time interval.

Gpload

`gpload` is a data loading utility that acts as an interface to the WarehousePG external table parallel loading feature.

Beware of using `gpload` as it can cause catalog bloat by creating and dropping external tables. Use `gpfdist` instead, since it provides the best performance.

`gpload` runs a load using a specification defined in a YAML-formatted control file. It performs the following operations:

- Invokes `gpfdist` processes
- Creates a temporary external table definition based on the source data defined
- Runs an `INSERT`, `UPDATE`, or `MERGE` operation to load the source data into the target table in the database
- Drops the temporary external table
- Cleans up `gpfdist` processes

The load is accomplished in a single transaction.

Best Practices

- Drop any indexes on an existing table before loading data and recreate the indexes after loading. Newly creating an index is faster than updating an index incrementally as each row is loaded.
- Deactivate automatic statistics collection during loading by setting the `gp_autostats_mode` configuration parameter to `NONE`.
- External tables are not intended for frequent or ad hoc access.
- When using `gpfdist`, maximize network bandwidth by running one `gpfdist` instance for each NIC on the ETL server. Divide the source data evenly between the `gpfdist` instances.
- When using `gpload`, run as many simultaneous `gpload` instances as resources allow. Take advantage of the CPU, memory, and networking resources available to increase the amount of data that can be transferred from ETL servers to the WarehousePG.
- Use the `SEGMENT REJECT LIMIT` clause of the `COPY` statement to set a limit for the number or percentage of rows that can have errors before the `COPY FROM` command is cancelled. The reject limit is per segment; when any one segment exceeds the limit, the command is cancelled and no rows are added. Use the `LOG ERRORS` clause to save error rows. If a row has errors in the formatting—for example missing or extra values, or incorrect data types—WarehousePG stores the error information and row internally. Use the `gp_read_error_log()` built-in SQL function to access this stored information.
- If the load has errors, run `VACUUM` on the table to recover space.
- After you load data into a table, run `VACUUM` on heap tables, including system catalogs, and `ANALYZE` on all tables. It is not necessary to run `VACUUM` on append-optimized tables. If the table is partitioned, you can vacuum and analyze just the partitions affected by the data load. These steps clean up any rows from prematurely ended loads, deletes, or updates and update statistics for the table.
- Recheck for segment skew in the table after loading a large amount of data. You can use a query like the following to check for skew:

```
SELECT gp_segment_id, count(*)
FROM schema.table
GROUP BY gp_segment_id ORDER BY 2;
```

- By default, `gpfdist` assumes a maximum record size of 32K. To load data records larger than 32K, you must increase the maximum row size parameter by specifying the `-m <*bytes*>` option on the `gpfdist` command line. If you use `gpload`, set the `MAX_LINE_LENGTH` parameter in the `gpload` control file.

Additional Information

See the *WarehousePG Reference Guide* for detailed instructions for loading data using `gpfdist` and `gpload`.

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6.8 Identifying and Mitigating Heap Table Performance Issues

Symptom:

The first scan of tuples after bulk data load, modification, or deletion jobs on heap tables are running slow or hanging.

Potential Cause:

When a workload involves a bulk load, modification, or deletion of data in a heap table, the first scan post-operation may generate a large amount of WAL data when checksums are enabled (`data_check_sums=true`) or hint bits are logged (`wal_log_hints=true`), leading to slow or hung jobs.

Affected workloads include: restoring from a backup, loading data with or `COPY`, cluster expansion, `CTAS` / `INSERT` / `UPDATE` / `DELETE` operations, and `ALTER TABLE` operations that modify tuples.

Explanation:

WarehousePG uses hint bits to mark tuples as created and/or deleted by transactions. Hint bits, when set, can help in determining visibility of tuples without expensive `pg_xact` and `pg_subtrans` commit log lookups.

Hint bits are updated for every tuple on the first scan of the tuple after its creation or deletion. Because hint bits are checked and set on a per-tuple basis, even a read can result in heavy writes. When data checksums are enabled for heap tables (the default), hint bit updates are always WAL-logged.

Solution:

If you have restored or loaded a complete database comprised primarily of heap tables, you may choose to run `VACUUM` against the entire database.

Alternatively, if you can identify the individual tables affected, you have two options:

1. Schedule and take a maintenance window and run `VACUUM` on the specific tables that have been loaded, updated, or deleted in bulk. This operation should scan all of the tuples and set and WAL-log the hint bits, taking the performance hit up-front.
2. Run `SELECT count(*) FROM <table-name>` on each table. This operation similarly scans all of the tuples and sets and WAL-logs the hint bits.

All subsequent scans as part of regular workloads on the tables should not be required to generate hints or their accompanying full page image WAL records.

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6.9 Security

Best practices to ensure the highest level of system security.

Basic Security Best Practices

- Secure the `gpadmin` system user. WarehousePG requires a UNIX user id to install and initialize the WarehousePG cluster. This system user is referred to as `gpadmin` in the WarehousePG documentation. The `gpadmin` user is the default database superuser in WarehousePG, as well as the file system owner of the WarehousePG installation and its underlying data files. The default administrator account is fundamental to the design of WarehousePG. The system cannot run without it, and there is no way to limit the access of the `gpadmin` user id. This `gpadmin` user can bypass all security features of WarehousePG. Anyone who logs on to a WarehousePG host with this user id can read, alter, or delete any data, including system catalog data and database access rights. Therefore, it is very important to secure the `gpadmin` user id and only allow essential system administrators access to it. Administrators should only log in to WarehousePG as `gpadmin` when performing certain system maintenance tasks (such as upgrade or expansion). Database users should never log on as `gpadmin`, and ETL or production workloads should never run as `gpadmin`.
- Assign a distinct role to each user who logs in. For logging and auditing purposes, each user who is allowed to log in to WarehousePG should be given their own database role. For applications or web services, consider creating a distinct role for each application or service. See "Creating New Roles (Users)" in the *WarehousePG Administrator Guide*.
- Use groups to manage access privileges. See "Creating Groups (Role Membership)" in the *WarehousePG Administrator Guide*.
- Limit users who have the `SUPERUSER` role attribute. Roles that are superusers bypass all access privilege checks in WarehousePG, as well as resource queuing. Only system administrators should be given superuser rights. See "Altering Role Attributes" in the *WarehousePG Administrator Guide*.

Password Strength Guidelines

To protect the network from intrusion, system administrators should verify the passwords used within an organization are strong ones. The following recommendations can strengthen a password:

- Minimum password length recommendation: At least 9 characters. MD5 passwords should be 15 characters or longer.
- Mix upper and lower case letters.
- Mix letters and numbers.
- Include non-alphanumeric characters.
- Pick a password you can remember.

The following are recommendations for password cracker software that you can use to determine the strength of a password.

- John The Ripper. A fast and flexible password cracking program. It allows the use of multiple word lists and is capable of brute-force password cracking. It is available online at http://www.openwall.com/john/.
- Crack. Perhaps the most well-known password cracking software, Crack is also very fast, though not as easy to use as John The Ripper. It can be found online at http://www.crypticide.com/alecm/security/crack/c50-faq.html.

The security of the entire system depends on the strength of the root password. This password should be at least 12 characters long and include a mix of capitalized letters, lowercase letters, special characters, and numbers. It should not be based on any dictionary word.

Password expiration parameters should be configured. The following commands must be run as `root` or using `sudo`.

Ensure the following line exists within the file `/etc/libuser.conf` under the `[import]` section.

```
login_defs = /etc/login.defs
```

Ensure no lines in the `[userdefaults]` section begin with the following text, as these words override settings from `/etc/login.defs`:

- `LU_SHADOWMAX`
- `LU_SHADOWMIN`
- `LU_SHADOWWARNING`

Ensure the following command produces no output. Any accounts listed by running this command should be locked.

```
grep "^+:" /etc/passwd /etc/shadow /etc/group
```

Note: We strongly recommend that customers change their passwords after initial setup.

```
cd /etc
chown root:root passwd shadow group gshadow
chmod 644 passwd group
chmod 400 shadow gshadow
```

Find all the files that are world-writable and that do not have their sticky bits set.

```
find / -xdev -type d \( -perm -0002 -a ! -perm -1000 \) -print
```

Set the sticky bit (`# chmod +t {dir}`) for all the directories that result from running the previous command.

Find all the files that are world-writable and fix each file listed.

```
find / -xdev -type f -perm -0002 -print
```

Set the right permissions (`# chmod o-w {file}`) for all the files generated by running the aforementioned command.

Find all the files that do not belong to a valid user or group and either assign an owner or remove the file, as appropriate.

```
find / -xdev \( -nouser -o -nogroup \) -print
```

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Find all the directories that are world-writable and ensure they are owned by either root or a system account (assuming only system accounts have a User ID lower than 500). If the command generates any output, verify the assignment is correct or reassign it to root.

```
find / -xdev -type d -perm -0002 -uid +500 -print
```

Authentication settings such as password quality, password expiration policy, password reuse, password retry attempts, and more can be configured using the Pluggable Authentication Modules (PAM) framework. PAM looks in the directory `/etc/pam.d` for application-specific configuration information. Running `authconfig` or `system-config-authentication` will re-write the PAM configuration files, destroying any manually made changes and replacing them with system defaults.

The default `pam_cracklib` PAM module provides strength checking for passwords. To configure `pam_cracklib` to require at least one uppercase character, lowercase character, digit, and special character, as recommended by the U.S. Department of Defense guidelines, edit the file `/etc/pam.d/system-auth` to include the following parameters in the line corresponding to password requisite `pam_cracklib.so try_first_pass`.

```
retry=3:
dcredit=-1. Require at least one digit
ucredit=-1. Require at least one upper case character
ocredit=-1. Require at least one special character
lcredit=-1. Require at least one lower case character
minlen=14. Require a minimum password length of 14.
```

For example:

```
password required pam_cracklib.so try_first_pass retry=3\minlen=14 dcredit=-1 ucredit=-1 ocredit=-1 lcredit=-1
```

These parameters can be set to reflect your security policy requirements. Note that the password restrictions are not applicable to the root password.

The `pam_tally2` PAM module provides the capability to lock out user accounts after a specified number of failed login attempts. To enforce password lockout, edit the file `/etc/pam.d/system-auth` to include the following lines:

- The first of the auth lines should include:

  ```
  auth required pam_tally2.so deny=5 onerr=fail unlock_time=900
  ```

- The first of the account lines should include:

  ```
  account required pam_tally2.so
  ```

Here, the deny parameter is set to limit the number of retries to 5 and the `unlock_time` has been set to 900 seconds to keep the account locked for 900 seconds before it is unlocked. These parameters may be configured appropriately to reflect your security policy requirements. A locked account can be manually unlocked using the `pam_tally2` utility:

```
/sbin/pam_tally2 --user {username} --reset
```

You can use PAM to limit the reuse of recent passwords. The remember option for the `pam_unix` module can be set to remember the recent passwords and prevent their reuse. To accomplish this, edit the appropriate line in `/etc/pam.d/system-auth` to include the remember option.

For example:

```
password sufficient pam_unix.so [ … existing_options …]
remember=5
```

You can set the number of previous passwords to remember to appropriately reflect your security policy requirements.

```
cd /etc
chown root:root passwd shadow group gshadow
chmod 644 passwd group
chmod 400 shadow gshadow
```

Parent topic: WarehousePG Best Practices

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6.10 Encrypting Data and Database Connections

Best practices for implementing encryption and managing keys.

Encryption can be used to protect data in a WarehousePG cluster in the following ways:

- Connections between clients and the coordinator database can be encrypted with SSL. This is enabled by setting the `ssl` server configuration parameter to `on` and editing the `pg_hba.conf` file. See "Encrypting Client/Server Connections" in the *WarehousePG Administrator Guide* for information about enabling SSL in WarehousePG.
- WarehousePG 4.2.1 and above allow SSL encryption of data in transit between the WarehousePG parallel file distribution server, `gpfdist`, and segment hosts. See Encrypting gpfdist Connections for more information.
- Network communications between hosts in the WarehousePG cluster can be encrypted using IPsec. An authenticated, encrypted VPN is established between every pair of hosts in the cluster. Check your operating system documentation for IPsec support, or consider a third-party solution such as that provided by Zettaset.
- The `pgcrypto` module of encryption/decryption functions protects data at rest in the database. Encryption at the column level protects sensitive information, such as passwords, Social Security numbers, or credit card numbers. See Encrypting Data in Tables using PGP for an example.

Best Practices

- Encryption ensures that data can be seen only by users who have the key required to decrypt the data.
- Encrypting and decrypting data has a performance cost; only encrypt data that requires encryption.
- Do performance testing before implementing any encryption solution in a production system.
- Server certificates in a production WarehousePG cluster should be signed by a certificate authority (CA) so that clients can authenticate the server. The CA may be local if all clients are local to the organization.
- Client connections to WarehousePG should use SSL encryption whenever the connection goes through an insecure link.
- A symmetric encryption scheme, where the same key is used to both encrypt and decrypt, has better performance than an asymmetric scheme and should be used when the key can be shared safely.
- Use functions from the pgcrypto module to encrypt data on disk. The data is encrypted and decrypted in the database process, so it is important to secure the client connection with SSL to avoid transmitting unencrypted data.
- Use the gpfdists protocol to secure ETL data as it is loaded into or unloaded from the database. SeeEncrypting gpfdist Connections.

Key Management

Whether you are using symmetric (single private key) or asymmetric (public and private key) cryptography, it is important to store the coordinator or private key securely. There are many options for storing encryption keys, for example, on a file system, key vault, encrypted USB, trusted platform module (TPM), or hardware security module (HSM).

Consider the following questions when planning for key management:

- Where will the keys be stored?
- When should keys expire?
- How are keys protected?
- How are keys accessed?
- How can keys be recovered and revoked?

The Open Web Application Security Project (OWASP) provides a very comprehensive guide to securing encryption keys.

Encrypting Data at Rest with pgcrypto

The pgcrypto module for WarehousePG provides functions for encrypting data at rest in the database. Administrators can encrypt columns with sensitive information, such as social security numbers or credit card numbers, to provide an extra layer of protection. Database data stored in encrypted form cannot be read by users who do not have the encryption key, and the data cannot be read directly from disk.

pgcrypto is installed by default when you install WarehousePG. You must explicitly enable pgcrypto in each database in which you want to use the module.

pgcrypto allows PGP encryption using symmetric and asymmetric encryption. Symmetric encryption encrypts and decrypts data using the same key and is faster than asymmetric encryption. It is the preferred method in an environment where exchanging secret keys is not an issue. With asymmetric encryption, a public key is used to encrypt data and a private key is used to decrypt data. This is slower then symmetric encryption and it requires a stronger key.

Using pgcrypto always comes at the cost of performance and maintainability. It is important to use encryption only with the data that requires it. Also, keep in mind that you cannot search encrypted data by indexing the data.

Before you implement in-database encryption, consider the following PGP limitations.

- No support for signing. That also means that it is not checked whether the encryption sub-key belongs to the coordinator key.
- No support for encryption key as coordinator key. This practice is generally discouraged, so this limitation should not be a problem.
- No support for several subkeys. This may seem like a problem, as this is common practice. On the other hand, you should not use your regular GPG/PGP keys with pgcrypto, but create new ones, as the usage scenario is rather different.

WarehousePG is compiled with zlib by default; this allows PGP encryption functions to compress data before encrypting. When compiled with OpenSSL, more algorithms will be available.

Because pgcrypto functions run inside the database server, the data and passwords move between pgcrypto and the client application in clear-text. For optimal security, you should connect locally or use SSL connections and you should trust both the system and database administrators.

pgcrypto configures itself according to the findings of the main PostgreSQL configure script.

When compiled with `zlib`, pgcrypto encryption functions are able to compress data before encrypting.

Pgcrypto has various levels of encryption ranging from basic to advanced built-in functions. The following table shows the supported encryption algorithms.

Value Functionality	Built-in	With OpenSSL
MD5	yes	yes
SHA1	yes	yes
SHA224/256/384/512	yes	yes
Other digest algorithms	no	yes
Blowfish	yes	yes
AES	yes	yes
DES/3DES/CAST5	no	yes
Raw Encryption	yes	yes

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Value Functionality	Built-in	With OpenSSL
PGP Symmetric-Key	yes	yes
PGP Public Key	yes	yes

Creating PGP Keys

To use PGP asymmetric encryption in WarehousePG, you must first create public and private keys and install them.

This section assumes you are installing WarehousePG on a Linux machine with the Gnu Privacy Guard (`gpg`) command line tool. It is recomended to use the latest version of GPG to create keys. Download and install Gnu Privacy Guard (GPG) for your operating system from https://www.gnupg.org/download/. On the GnuPG website you will find installers for popular Linux distributions and links for Windows and Mac OS X installers.

1. As root, run the following command and choose option 1 from the menu:

```
# gpg --gen-key
gpg (GnuPG) 2.0.14; Copyright (C) 2009 Free Software Foundation, Inc.
This is free software: you are free to change and redistribute it.
There is NO WARRANTY, to the extent permitted by law.

gpg: directory `/root/.gnupg' created
gpg: new configuration file `/root/.gnupg/gpg.conf' created
gpg: WARNING: options in `/root/.gnupg/gpg.conf' are not yet active during this run
gpg: keyring `/root/.gnupg/secring.gpg' created
gpg: keyring `/root/.gnupg/pubring.gpg' created
Please select what kind of key you want:
 (1) RSA and RSA (default)
 (2) DSA and Elgamal
 (3) DSA (sign only)
 (4) RSA (sign only)
Your selection? 1
```

2. Respond to the prompts and follow the instructions, as shown in this example:

```
RSA keys may be between 1024 and 4096 bits long.
What keysize do you want? (2048) Press enter to accept default key size
Requested keysize is 2048 bits
Please specify how long the key should be valid.
 0 = key does not expire
 <n> = key expires in n days
 <n>w = key expires in n weeks
 <n>m = key expires in n months
 <n>y = key expires in n years
 Key is valid for? (0) 365
Key expires at Wed 13 Jan 2016 10:35:39 AM PST
Is this correct? (y/N) y

GnuPG needs to construct a user ID to identify your key.

Real name: John Doe
Email address: jdoe@email.com
Comment:
You selected this USER-ID:
 "John Doe <jdoe@email.com>"

Change (N)ame, (C)omment, (E)mail or (O)kay/(Q)uit? O
You need a Passphrase to protect your secret key.
(For this demo the passphrase is blank.)
can't connect to `/root/.gnupg/S.gpg-agent': No such file or directory
You don't want a passphrase - this is probably a *bad* idea!
I will do it anyway.  You can change your passphrase at any time,
using this program with the option "--edit-key".

We need to generate a lot of random bytes. It is a good idea to perform
some other action (type on the keyboard, move the mouse, utilize the
disks) during the prime generation; this gives the random number
generator a better chance to gain enough entropy.
We need to generate a lot of random bytes. It is a good idea to perform
some other action (type on the keyboard, move the mouse, utilize the
disks) during the prime generation; this gives the random number
generator a better chance to gain enough entropy.
gpg: /root/.gnupg/trustdb.gpg: trustdb created
gpg: key 2027CC30 marked as ultimately trusted
public and secret key created and signed.

gpg:  checking the trustdbgpg:
      3 marginal(s) needed, 1 complete(s) needed, PGP trust model
gpg:  depth: 0  valid1  signed0  trust: 0-, 0q, 0n, 0m, 0f, 1u
gpg:  next trustdb check due at 2016-01-13
pub   2048R/2027CC30 2015-01-13 [expires: 2016-01-13]
      Key fingerprint = 7EDA 6AD0 F5E0 400F 4D45   3259 077D 725E 2027 CC30
uid                  John Doe <jdoe@email.com>
sub   2048R/4FD2EFBB 2015-01-13 [expires: 2016-01-13]
```

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3. List the PGP keys by entering the following command:

```
gpg --list-secret-keys
/root/.gnupg/secring.gpg
------------------------
sec   2048R/2027CC30 2015-01-13 [expires: 2016-01-13]
uid                  John Doe <jdoe@email.com>
ssb   2048R/4FD2EFBB 2015-01-13
```

`2027CC30 is the public key and will be used to *encrypt* data in the database. 4FD2EFBB is the private (secret) key and will be used to *decrypt* data.`

4. Export the keys using the following commands:

```
# gpg -a --export 4FD2EFBB > public.key
# gpg -a --export-secret-keys 2027CC30 > secret.key
```

See the pgcrypto documentation for more information about PGP encryption functions.

Encrypting Data in Tables using PGP

This section shows how to encrypt data inserted into a column using the PGP keys you generated.

1. Dump the contents of the `public.key` file and then copy it to the clipboard:

```
# cat public.key
-----BEGIN PGP PUBLIC KEY BLOCK-----
Version: GnuPG v2.0.14 (GNU/Linux)

mQENBFS1Zf0BCADNw8Qvk1V1C36Kfcwd3Kpm/dijPfRyyEwB6PqKyA05jtWiXZTh
2His1ojSP6LI0cSkIqMU9LAlncecZhRIhBhuVgKlGSgd9texg2nnSL9Admqik/yX
R5syVKG+qcdWuvyZg9oOOmeyjhc3n+kkbRTEMuM3flbMs8shOwzMvstCUVmuHU/V
. . .
WH+N2lasoUaoJjb2kQGhLOnFbJuevkyBylRz+hI/+8rJKcZOjQkmmK8Hkk8qb5x/
HMUc55H0g2qQAY0BpnJHgOOQ45Q6pk3G2/7Dbek5WJ6K1wUrFy51sNlGWE8pvgEx
/UUZB+dYqCwtvX0nnBu1KNCmk2AkEcFK3YoliCxomdOxhFOv9AKjjojDyC65KJci
Pv2MikPS2fKOAg1R3LpMa8zDEtl4w3vckPQNrQNnYuUtfj6ZoCxv
=XZ8J
-----END PGP PUBLIC KEY BLOCK-----
```

2. Enable the `pgcrypto` extension:

```
CREATE EXTENSION pgcrypto;
```

3. Create a table called `userssn` and insert some sensitive data, social security numbers for Bob and Alice, in this example. Paste the public.key contents after "dearmor(".

```
CREATE TABLE userssn( ssn_id SERIAL PRIMARY KEY,
    username varchar(100), ssn bytea);

INSERT INTO userssn(username, ssn)
SELECT robotccs.username, pgp_pub_encrypt(robotccs.ssn, keys.pubkey) AS
ssn
FROM (
VALUES ('Alice', '123-45-6788'), ('Bob', '123-45-6799'))
AS robotccs(username, ssn)
CROSS JOIN (SELECT dearmor('-----BEGIN PGP PUBLIC KEY BLOCK-----
Version: GnuPG v2.0.22 (GNU/Linux)

mQENBGCb7NQBCADfCoMFIbjb6dup8eJHgTpo8TILiIubqhqASHqUPe/v3eI+p9W8
mZbTZo+EUFCJmFZx8RWw0s0t4DG3fzBQOv5y2oBEu9sg3ofgFkK6TaQV7ueZfifx
S1DxQE8kWEFrGsB13VJlLMMLPr4tdjtaYOdn5b+3N4/8GOJALn2CeWrP8lIXaget
. . .
T9dl2HhMOatlVhBUOcYrqSBEWgwtQbX36hFzhp1tNCDOvtDpsfLNHJr8vIpXAeyz
juW0/vEgrAtSK8P2/kmRsmNM/LJIbCBHD+tTSTHZ194+QYUc1KYXW4NV5LLW08MY
skETyovyVDFYEpTMVrRKJYLROhEBv8cqYgKq1XtcIH8eiwJIZ0L1L/1Cw7Z/BpRT
WbrwmhXTpqi+/Vdm7q9gPFoAfw/ur44hJGsc13bQxdmluTigSN2f+qf9RzA=
=xdQf
-----END PGP PUBLIC KEY BLOCK-----')  as pubkey) AS keys;
```

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4. Verify that the `ssn` column is encrypted.

```
test_db=# select * from userssn;
ssn_id   | 1
username | Alice
ssn      | \301\300L\003\235M%_O\322\357\273\001\010\000\272\227\010\341\216\360\217C\020\261)_\367
[\227\034\313:C\354d<\337\006Q\351('\2330\031lX\263Qf\341\262\200\3015\235\036AK\242fL+\315g\322
7u\270*\304\361\355\220\021\330"\200%\264\274}R\213\377\363\235\366\030\023)\364!\331\303\237t\277=
f \015\004\242\231\263\225%\032\271a\001\035\277\021\375X\232\304\305/\340\334\0131\325\344[~\362\0
37-\251\336\303\340\377_\011\275\301/MY\334\343\245\244\372y\257S\374\230\346\277\373W\346\230\276\
017fi\226Q\307\012\326\3646\000\326\005:E\364W\252=zz\010(:\343Y\237\257iqU\0326\350=v0\362\327\350\
315G^\027:K_9\254\362\354\215<\001\304\357\331\355\323,\302\213Fe\265\315\232\367\254\245%(\\\373
4\254\230\331\356\006B\257\333\326H\022\013\353\216F?\023\220\370\035vH5/\227\344b\322\227\026\362=\
42\033\322<\001}\243\224;)\030zqX\214\340\221\035\275U\345\327\214\032\351\223c\2442\345\304K\016\
011\214\307\227\237\270\026`R\205\205a~1\263\236[\037C\260\031\205\374\245\317\033k|\366\253\037
---------+-------------------------------------------------------------------------------------------
-------------------------------------------------------------------------------------------------
-------------------------------------------------------------------------------------------------
-------------------------------------------------------------------------------------------------
-------------------------------------------------------------------------------------------------
-------------------------------------------------------------------------------------------------
-------------------------------------------------------------------------------------------------
-------------------------------------------------------------------------------------------------
-------------------------------------------------------------------------------------------------
-------------------------------------------------------------------------
ssn_id   | 2
username | Bob
ssn      | \301\300L\003\235M%_O\322\357\273\001\007\377t>\345\343,\200\256\272\300\012\033M4\265\032L
L[v\262k\244\2435\264\232B\357\370d9\375\011\002\327\235<\246\210b\030\012\337@\226Z\361\246\032\00
7`\012c\353]\355d7\360T\335\314\367\370;X\371\350*\231\212\260B\010#RQ0\223\253c7\0132b\355\242\233\34
1\000\370\370\366\013\022\357\005i\202~\005\\z\301o\012\230Z\014\362\244\324&\243g\351\362\325\375
\213\032\226$\2751\256XR\346k\266\030\234\267\201vUh\004\250\337A\231\223u\247\366/i\022\275\276\350\2
20\316\306|\203+\010\261;\232\254tp\255\243\261\373Rq;\316w\357\006\207\374U\333\365\365\245hg\031\005
\322\347ea\220\015l\212g\337\264\336b\263\004\311\210.4\340G+\221\274D\035\375\2216\241`\346a0\273wE\2
12\342y^\202\262|A7\202t\240\333p\345G\373\253\243oCO\011\360\247\211\014\024{\272\271\322<\001\267
\347\240\005\213\0078\036\210\307$\317\322\311\222\035\354\006<\266\264\004\376\251q\256\220(+\030\
3270\013c\327\272\212%\363\033\252\322\337\354\276\225\232\201\212^\304\210\2269@\3230\370{
```

5. Extract the public.key ID from the database:

```
SELECT pgp_key_id(dearmor('-----BEGIN PGP PUBLIC KEY BLOCK-----
Version: GnuPG v2.0.14 (GNU/Linux)

mQENBFS1Zf0BCADNw8Qvk1V1C36Kfcwd3Kpm/dijPfRyyEwB6PqKyA05jtWiXZTh
2His1ojSP6LI0cSkIqMU9LAlncecZhRIhBhuVgKlGSgd9texg2nnSL9Admqik/yX
R5syVKG+qcdWuvyZg9oOOmeyjhc3n+kkbRTEMuM3flbMs8shOwzMvstCUVmuHU/V
. . .
WH+N2lasoUaoJjb2kQGhLOnFbJuevkyBylRz+hI/+8rJKcZOjQkmmK8Hkk8qb5x/
HMUc55H0g2qQAY0BpnJHgOOQ45Q6pk3G2/7Dbek5WJ6K1wUrFy51sNlGWE8pvgEx
/UUZB+dYqCwtvX0nnBu1KNCmk2AkEcFK3YoliCxomdOxhFOv9AKjjojDyC65KJci
Pv2MikPS2fKOAg1R3LpMa8zDEtl4w3vckPQNrQNnYuUtfj6ZoCxv
=XZ8J
-----END PGP PUBLIC KEY BLOCK-----'));

pgp_key_id | 9D4D255F4FD2EFBB
```

This shows that the PGP key ID used to encrypt the `ssn` column is 9D4D255F4FD2EFBB. It is recommended to perform this step whenever a new key is created and then store the ID for tracking.

You can use this key to see which key pair was used to encrypt the data:

```
SELECT username, pgp_key_id(ssn) As key_used
FROM userssn;
username | Bob
key_used | 9D4D255F4FD2EFBB
---------+-----------------
username | Alice
key_used | 9D4D255F4FD2EFBB
```

> **Note** Different keys may have the same ID. This is rare, but is a normal event. The client application should try to decrypt with each one to see which fits — like handling `ANYKEY`. See pgp_key_id() in the pgcrypto documentation.

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6. Decrypt the data using the private key.

```
SELECT username, pgp_pub_decrypt(ssn, keys.privkey)
                AS decrypted_ssn FROM userssn
                CROSS JOIN
                (SELECT dearmor('-----BEGIN PGP PRIVATE KEY BLOCK-----
Version: GnuPG v2.0.14 (GNU/Linux)

lQOYBFS1Zf0BCADNw8Qvk1V1C36Kfcwd3Kpm/dijPfRyyEwB6PqKyA05jtWiXZTh
2His1ojSP6LI0cSkIqMU9LAlncecZhRIhBhuVgKlGSgd9texg2nnSL9Admqik/yX
R5syVKG+qcdWuvyZg9oOOmeyjhc3n+kkbRTEMuM3flbMs8shOwzMvstCUVmuHU/V
. . .
QNPSvz62WH+N2lasoUaoJjb2kQGhLOnFbJuevkyBylRz+hI/+8rJKcZOjQkmmK8H
kk8qb5x/HMUc55H0g2qQAY0BpnJHgOOQ45Q6pk3G2/7Dbek5WJ6K1wUrFy51sNlG
WE8pvgEx/UUZB+dYqCwtvX0nnBu1KNCmk2AkEcFK3YoliCxomdOxhFOv9AKjjojD
yC65KJciPv2MikPS2fKOAg1R3LpMa8zDEtl4w3vckPQNrQNnYuUtfj6ZoCxv
=fa+6
-----END PGP PRIVATE KEY BLOCK-----') AS privkey) AS keys;

username | decrypted_ssn
----------+---------------
 Alice    | 123-45-6788
 Bob      | 123-45-6799
(2 rows)
```

If you created a key with passphrase, you may have to enter it here. However for the purpose of this example, the passphrase is blank.

Encrypting gpfdist Connections

The `gpfdists` protocol is a secure version of the `gpfdist` protocol that securely identifies the file server and the WarehousePG and encrypts the communications between them. Using `gpfdists` protects against eavesdropping and man-in-the-middle attacks.

The `gpfdists` protocol implements client/server SSL security with the following notable features:

- Client certificates are required.
- Multilingual certificates are not supported.
- A Certificate Revocation List (CRL) is not supported.
- The TLSv1 protocol is used with the `TLS_RSA_WITH_AES_128_CBC_SHA` encryption algorithm. These SSL parameters cannot be changed.
- SSL renegotiation is supported.
- The SSL ignore host mismatch parameter is set to false.
- Private keys containing a passphrase are not supported for the `gpfdist` file server (server.key) or for the WarehousePG (client.key).
- It is the user's responsibility to issue certificates that are appropriate for the operating system in use. Generally, converting certificates to the required format is supported, for example using the SSL Converter at https://www.sslshopper.com/ssl-converter.html.

A `gpfdist` server started with the `--ssl` option can only communicate with the `gpfdists` protocol. A `gpfdist` server started without the `--ssl` option can only communicate with the `gpfdist` protocol. For more detail about `gpfdist` refer to the *WarehousePG Administrator Guide*.

There are two ways to enable the `gpfdists` protocol:

- Run `gpfdist` with the `--ssl` option and then use the `gpfdists` protocol in the `LOCATION` clause of a `CREATE EXTERNAL TABLE` statement.
- Use a YAML control file with the SSL option set to true and run `gpload`. Running `gpload` starts the `gpfdist` server with the `--ssl` option and then uses the `gpfdists` protocol.

When using gpfdists, the following client certificates must be located in the `$PGDATA/gpfdists` directory on each segment:

- The client certificate file, `client.crt`
- The client private key file, `client.key`
- The trusted certificate authorities, `root.crt`

> **Important** Do not protect the private key with a passphrase. The server does not prompt for a passphrase for the private key, and loading data fails with an error if one is required.

When using `gpload` with SSL you specify the location of the server certificates in the YAML control file. When using `gpfdist` with SSL, you specify the location of the server certificates with the --ssl option.

The following example shows how to securely load data into an external table. The example creates a readable external table named `ext_expenses` from all files with the `txt` extension, using the `gpfdists` protocol. The files are formatted with a pipe (`|`) as the column delimiter and an empty space as null.

1. Run `gpfdist` with the `--ssl` option on the segment hosts.

2. Log into the database and run the following command:

```
=# CREATE EXTERNAL TABLE ext_expenses
   ( name text, date date, amount float4, category text, desc1 text )
LOCATION ('gpfdists://etlhost-1:8081/*.txt', 'gpfdists://etlhost-2:8082/*.txt')
FORMAT 'TEXT' ( DELIMITER '|' NULL ' ') ;
```

Parent topic: WarehousePG Best Practices

SHA2 algorithms were added to OpenSSL in version 0.9.8. For older versions, pgcrypto will use built-in code Any digest algorithm OpenSSL supports is automatically picked up. This is not possible with ciphers, which need to be supported explicitly. AES is included in OpenSSL since version 0.9.7. For older versions, pgcrypto will use built-in code.

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6.11 Tuning SQL Queries

The WarehousePG cost-based optimizer evaluates many strategies for running a query and chooses the least costly method.

Like other RDBMS optimizers, the WarehousePG optimizer takes into account factors such as the number of rows in tables to be joined, availability of indexes, and cardinality of column data when calculating the costs of alternative execution plans. The optimizer also accounts for the location of the data, preferring to perform as much of the work as possible on the segments and to minimize the amount of data that must be transmitted between segments to complete the query.

When a query runs slower than you expect, you can view the plan the optimizer selected as well as the cost it calculated for each step of the plan. This will help you determine which steps are consuming the most resources and then modify the query or the schema to provide the optimizer with more efficient alternatives. You use the SQL `EXPLAIN` statement to view the plan for a query.

The optimizer produces plans based on statistics generated for tables. It is important to have accurate statistics to produce the best plan. See Updating Statistics with ANALYZE in this guide for information about updating statistics.

Parent topic: WarehousePG Best Practices

How to Generate Explain Plans

The `EXPLAIN` and `EXPLAIN ANALYZE` statements are useful tools to identify opportunities to improve query performance. `EXPLAIN` displays the query plan and estimated costs for a query, but does not run the query. `EXPLAIN ANALYZE` runs the query in addition to displaying the query plan. `EXPLAIN ANALYZE` discards any output from the `SELECT` statement; however, other operations in the statement are performed (for example, `INSERT`, `UPDATE`, or `DELETE`). To use `EXPLAIN ANALYZE` on a DML statement without letting the command affect the data, explicitly use `EXPLAIN ANALYZE` in a transaction (`BEGIN; EXPLAIN ANALYZE ...; ROLLBACK;`).

`EXPLAIN ANALYZE` runs the statement in addition to displaying the plan with additional information as follows:

- Total elapsed time (in milliseconds) to run the query
- Number of workers (segments) involved in a plan node operation
- Maximum number of rows returned by the segment (and its segment ID) that produced the most rows for an operation
- The memory used by the operation
- Time (in milliseconds) it took to retrieve the first row from the segment that produced the most rows, and the total time taken to retrieve all rows from that segment.

How to Read Explain Plans

An explain plan is a report detailing the steps the WarehousePG optimizer has determined it will follow to run a query. The plan is a tree of nodes, read from bottom to top, with each node passing its result to the node directly above. Each node represents a step in the plan, and one line for each node identifies the operation performed in that step—for example, a scan, join, aggregation, or sort operation. The node also identifies the method used to perform the operation. The method for a scan operation, for example, may be a sequential scan or an index scan. A join operation may perform a hash join or nested loop join.

Following is an explain plan for a simple query. This query finds the number of rows in the contributions table stored at each segment.

```
gpadmin=# EXPLAIN SELECT gp_segment_id, count(*)
                  FROM contributions
                  GROUP BY gp_segment_id;
                                  QUERY PLAN
------------------------------------------------------------------------------
 Gather Motion 2:1  (slice2; segments: 2)  (cost=0.00..431.00 rows=2 width=12)
   ->  GroupAggregate  (cost=0.00..431.00 rows=1 width=12)
         Group By: gp_segment_id
         ->  Sort  (cost=0.00..431.00 rows=1 width=12)
               Sort Key: gp_segment_id
               ->  Redistribute Motion 2:2  (slice1; segments: 2)  (cost=0.00..431.00 rows=1 width=12)
                     Hash Key: gp_segment_id
                     ->  Result  (cost=0.00..431.00 rows=1 width=12)
                           ->  GroupAggregate  (cost=0.00..431.00 rows=1 width=12)
                                 Group By: gp_segment_id
                                 ->  Sort  (cost=0.00..431.00 rows=7 width=4)
                                       Sort Key: gp_segment_id
                                       ->  Seq Scan on table1  (cost=0.00..431.00 rows=7 width=4)
 Optimizer: GPORCA
(14 rows)
```

This plan has eight nodes – Seq Scan, Sort, GroupAggregate, Result, Redistribute Motion, Sort, GroupAggregate, and finally Gather Motion. Each node contains three cost estimates: cost (in sequential page reads), the number of rows, and the width of the rows.

The cost is a two-part estimate. A cost of 1.0 is equal to one sequential disk page read. The first part of the estimate is the start-up cost, which is the cost of getting the first row. The second estimate is the total cost, the cost of getting all of the rows.

The rows estimate is the number of rows output by the plan node. The number may be lower than the actual number of rows processed or scanned by the plan node, reflecting the estimated selectivity of `WHERE` clause conditions. The total cost assumes that all rows will be retrieved, which may not always be the case (for example, if you use a `LIMIT` clause).

The width estimate is the total width, in bytes, of all the columns output by the plan node.

The cost estimates in a node include the costs of all its child nodes, so the top-most node of the plan, usually a Gather Motion, has the estimated total execution costs for the plan. This is this number that the query planner seeks to minimize.

Scan operators scan through rows in a table to find a set of rows. There are different scan operators for different types of storage. They include the following:

- Seq Scan on tables — scans all rows in the table.
- Index Scan — traverses an index to fetch the rows from the table.
- Bitmap Heap Scan — gathers pointers to rows in a table from an index and sorts by location on disk. (The operator is called a Bitmap Heap Scan, even for append-only tables.)
- Dynamic Seq Scan — chooses partitions to scan using a partition selection function.

Join operators include the following:

- Hash Join – builds a hash table from the smaller table with the join column(s) as hash key. Then scans the larger table, calculating the hash key for the join column(s) and probing the hash table to find the rows with the same hash key. Hash joins are typically the fastest joins in WarehousePG. The Hash Cond in the explain plan identifies the columns that are joined.

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- Nested Loop – iterates through rows in the larger dataset, scanning the rows in the smaller dataset on each iteration. The Nested Loop join requires the broadcast of one of the tables so that all rows in one table can be compared to all rows in the other table. It performs well for small tables or tables that are limited by using an index. It is also used for Cartesian joins and range joins. There are performance implications when using a Nested Loop join with large tables. For plan nodes that contain a Nested Loop join operator, validate the SQL and ensure that the results are what is intended. Set the `enable_nestloop` server configuration parameter to OFF (default) to favor Hash Join.
- Merge Join – sorts both datasets and merges them together. A merge join is fast for pre-ordered data, but is very rare in the real world. To favor Merge Joins over Hash Joins, set the `enable_mergejoin` system configuration parameter to ON.

Some query plan nodes specify motion operations. Motion operations move rows between segments when required to process the query. The node identifies the method used to perform the motion operation. Motion operators include the following:

- Broadcast motion – each segment sends its own, individual rows to all other segments so that every segment instance has a complete local copy of the table. A Broadcast motion may not be as optimal as a Redistribute motion, so the optimizer typically only selects a Broadcast motion for small tables. A Broadcast motion is not acceptable for large tables. In the case where data was not distributed on the join key, a dynamic redistribution of the needed rows from one of the tables to another segment is performed.
- Redistribute motion – each segment rehashes the data and sends the rows to the appropriate segments according to hash key.
- Gather motion – result data from all segments is assembled into a single stream. This is the final operation for most query plans.

Other operators that occur in query plans include the following:

- Materialize – the planner materializes a subselect once so it does not have to repeat the work for each top-level row.
- InitPlan – a pre-query, used in dynamic partition elimination, performed when the values the planner needs to identify partitions to scan are unknown until execution time.
- Sort – sort rows in preparation for another operation requiring ordered rows, such as an Aggregation or Merge Join.
- Group By – groups rows by one or more columns.
- Group/Hash Aggregate – aggregates rows using a hash.
- Append – concatenates data sets, for example when combining rows scanned from partitions in a partitioned table.
- Filter – selects rows using criteria from a `WHERE` clause.
- Limit – limits the number of rows returned.

Optimizing WarehousePG Queries

This topic describes WarehousePG features and programming practices that can be used to enhance system performance in some situations.

To analyze query plans, first identify the plan nodes where the estimated cost to perform the operation is very high. Determine if the estimated number of rows and cost seems reasonable relative to the number of rows for the operation performed.

If using partitioning, validate that partition elimination is achieved. To achieve partition elimination the query predicate (`WHERE` clause) must be the same as the partitioning criteria. Also, the `WHERE` clause must not contain an explicit value and cannot contain a subquery.

Review the execution order of the query plan tree. Review the estimated number of rows. You want the execution order to build on the smaller tables or hash join result and probe with larger tables. Optimally, the largest table is used for the final join or probe to reduce the number of rows being passed up the tree to the topmost plan nodes. If the analysis reveals that the order of execution builds and/or probes is not optimal ensure that database statistics are up to date. Running `ANALYZE` will likely address this and produce an optimal query plan.

Look for evidence of computational skew. Computational skew occurs during query execution when execution of operators such as Hash Aggregate and Hash Join cause uneven execution on the segments. More CPU and memory are used on some segments than others, resulting in less than optimal execution. The cause could be joins, sorts, or aggregations on columns that have low cardinality or non-uniform distributions. You can detect computational skew in the output of the `EXPLAIN ANALYZE` statement for a query. Each node includes a count of the maximum rows processed by any one segment and the average rows processed by all segments. If the maximum row count is much higher than the average, at least one segment has performed much more work than the others and computational skew should be suspected for that operator.

Identify plan nodes where a Sort or Aggregate operation is performed. Hidden inside an Aggregate operation is a Sort. If the Sort or Aggregate operation involves a large number of rows, there is an opportunity to improve query performance. A HashAggregate operation is preferred over Sort and Aggregate operations when a large number of rows are required to be sorted. Usually a Sort operation is chosen by the optimizer due to the SQL construct; that is, due to the way the SQL is written. Most Sort operations can be replaced with a HashAggregate if the query is rewritten. To favor a HashAggregate operation over a Sort and Aggregate operation ensure that the `enable_groupagg` server configuration parameter is set to `ON`.

When an explain plan shows a broadcast motion with a large number of rows, you should attempt to eliminate the broadcast motion. One way to do this is to use the `gp_segments_for_planner` server configuration parameter to increase the cost estimate of the motion so that alternatives are favored. The `gp_segments_for_planner` variable tells the query planner how many primary segments to use in its calculations. The default value is zero, which tells the planner to use the actual number of primary segments in estimates. Increasing the number of primary segments increases the cost of the motion, thereby favoring a redistribute motion over a broadcast motion. For example, setting `gp_segments_for_planner = 100000` tells the planner that there are 100,000 segments. Conversely, to influence the optimizer to broadcast a table and not redistribute it, set `gp_segments_for_planner` to a low number, for example 2.

WarehousePG Grouping Extensions

WarehousePG aggregation extensions to the `GROUP BY` clause can perform some common calculations in the database more efficiently than in application or procedure code:

- `GROUP BY ROLLUP(*col1*, *col2*, *col3*)`
- `GROUP BY CUBE(*col1*, *col2*, *col3*)`
- `GROUP BY GROUPING SETS((*col1*, *col2*), (*col1*, *col3*))`

A `ROLLUP` grouping creates aggregate subtotals that roll up from the most detailed level to a grand total, following a list of grouping columns (or expressions). `ROLLUP` takes an ordered list of grouping columns, calculates the standard aggregate values specified in the `GROUP BY` clause, then creates progressively higher-level subtotals, moving from right to left through the list. Finally, it creates a grand total.

A `CUBE` grouping creates subtotals for all of the possible combinations of the given list of grouping columns (or expressions). In multidimensional analysis terms, `CUBE` generates all the subtotals that could be calculated for a data cube with the specified dimensions.

You can selectively specify the set of groups that you want to create using a `GROUPING SETS` expression. This allows precise specification across multiple dimensions without computing a whole `ROLLUP` or `CUBE`.

Refer to the *WarehousePG Reference Guide* for details of these clauses.

Window Functions

Window functions apply an aggregation or ranking function over partitions of the result set—for example, `sum(population) over (partition by city)`. Window functions are powerful and, because they do all of the work in the database, they have performance advantages over front-end tools that produce similar results by retrieving detail rows from the database and reprocessing them.

- The `row_number()` window function produces row numbers for the rows in a partition, for example, `row_number() over (order by id)`.
- When a query plan indicates that a table is scanned in more than one operation, you may be able to use window functions to reduce the number of scans.
- It is often possible to eliminate self joins by using window functions.

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6.12 High Availability

WarehousePG supports highly available, fault-tolerant database services when you enable and properly configure WarehousePG high availability features. To guarantee a required level of service, each component must have a standby ready to take its place if it should fail.

Parent topic: WarehousePG Best Practices

Disk Storage

With the WarehousePG "shared-nothing" MPP architecture, the coordinator host and segment hosts each have their own dedicated memory and disk storage, and each coordinator or segment instance has its own independent data directory. For both reliability and high performance, a hardware RAID storage solution with from 8 to 24 disks is recommended. A larger number of disks improves I/O throughput when using RAID 5 (or 6) because striping increases parallel disk I/O. The RAID controller can continue to function with a failed disk because it saves parity data on each disk in a way that it can reconstruct the data on any failed member of the array. If a hot spare is configured (or an operator replaces the failed disk with a new one) the controller rebuilds the failed disk automatically.

RAID 1 exactly mirrors disks, so if a disk fails, a replacement is immediately available with performance equivalent to that before the failure. With RAID 5 each I/O for data on the failed array member must be reconstructed from data on the remaining active drives until the replacement disk is rebuilt, so there is a temporary performance degradation. If the WarehousePG coordinator and segments are mirrored, you can switch any affected WarehousePG instances to their mirrors during the rebuild to maintain acceptable performance.

A RAID disk array can still be a single point of failure, for example, if the entire RAID volume fails. At the hardware level, you can protect against a disk array failure by mirroring the array, using either host operating system mirroring or RAID controller mirroring, if supported.

It is important to regularly monitor available disk space on each segment host. Query the `gp_disk_free` external table in the `gptoolkit` schema to view disk space available on the segments. This view runs the Linux `df` command. Be sure to check that there is sufficient disk space before performing operations that consume large amounts of disk, such as copying a large table.

See `gp_toolkit.gp_disk_free` in the *WarehousePG Reference Guide*.

Best Practices

- Use a hardware RAID storage solution with 8 to 24 disks.
- Use RAID 1, 5, or 6 so that the disk array can tolerate a failed disk.
- Configure a hot spare in the disk array to allow rebuild to begin automatically when disk failure is detected.
- Protect against failure of the entire disk array and degradation during rebuilds by mirroring the RAID volume.
- Monitor disk utilization regularly and add additional space when needed.
- Monitor segment skew to ensure that data is distributed evenly and storage is consumed evenly at all segments.

Coordinator Mirroring

The WarehousePG coordinator instance is clients' single point of access to the system. The coordinator instance stores the global system catalog, the set of system tables that store metadata about the database instance, but no user data. If an unmirrored coordinator instance fails or becomes inaccessible, the WarehousePG instance is effectively off-line, since the entry point to the system has been lost. For this reason, a standby coordinator must be ready to take over if the primary coordinator fails.

Coordinator mirroring uses two processes, a sender on the active coordinator host and a receiver on the mirror host, to synchronize the mirror with the coordinator. As changes are applied to the coordinator system catalogs, the active coordinator streams its write-ahead log (WAL) to the mirror so that each transaction applied on the coordinator is applied on the mirror.

The mirror is a *warm standby*. If the primary coordinator fails, switching to the standby requires an administrative user to run the `gpactivatestandby` utility on the standby host so that it begins to accept client connections. Clients must reconnect to the new coordinator and will lose any work that was not committed when the primary failed.

See "Enabling High Availability Features" in the *WarehousePG Administrator Guide* for more information.

Best Practices

- Set up a standby coordinator instance—a *mirror*—to take over if the primary coordinator fails.
- The standby can be on the same host or on a different host, but it is best practice to place it on a different host from the primary coordinator to protect against host failure.
- Plan how to switch clients to the new coordinator instance when a failure occurs, for example, by updating the coordinator address in DNS.
- Set up monitoring to send notifications in a system monitoring application or by email when the primary fails.

Segment Mirroring

WarehousePG segment instances each store and manage a portion of the database data, with coordination from the coordinator instance. If any unmirrored segment fails, the database may have to be shutdown and recovered, and transactions occurring after the most recent backup could be lost. Mirroring segments is, therefore, an essential element of a high availability solution.

A segment mirror is a hot standby for a primary segment. WarehousePG detects when a segment is unavailable and automatically activates the mirror. During normal operation, when the primary segment instance is active, data is replicated from the primary to the mirror in two ways:

- The transaction commit log is replicated from the primary to the mirror before the transaction is committed. This ensures that if the mirror is activated, the changes made by the last successful transaction at the primary are present at the mirror. When the mirror is activated, transactions in the log are applied to tables in the mirror.

- Second, segment mirroring uses physical file replication to update heap tables. WarehousePG Server stores table data on disk as fixed-size blocks packed with tuples. To optimize disk I/O, blocks are cached in memory until the cache fills and some blocks must be evicted to make room for newly updated blocks. When a block is evicted from the cache it is written to disk and replicated over the network to the mirror. Because of the caching mechanism, table updates at the mirror can lag behind the primary. However, because the transaction log is also replicated, the mirror remains consistent with the primary. If the mirror is activated, the activation process updates the tables with any unapplied changes in the transaction commit log.

When the acting primary is unable to access its mirror, replication stops and state of the primary changes to "Change Tracking." The primary saves changes that have not been replicated to the mirror in a system table to be replicated to the mirror when it is back on-line.

The coordinator automatically detects segment failures and activates the mirror. Transactions in progress at the time of failure are restarted using the new primary. Depending on how mirrors are deployed on the hosts, the database system may be unbalanced until the original primary segment is recovered. For example, if each segment host has four primary segments and four mirror segments, and a mirror is activated on one host, that host will have five active primary segments. Queries are not complete until the last segment has finished its work, so performance can be degraded until the balance is restored by recovering the original primary.

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Administrators perform the recovery while WarehousePG is up and running by running the `gprecoverseg` utility. This utility locates the failed segments, verifies they are valid, and compares the transactional state with the currently active segment to determine changes made while the segment was offline. `gprecoverseg` synchronizes the changed database files with the active segment and brings the segment back online.

It is important to reserve enough memory and CPU resources on segment hosts to allow for increased activity from mirrors that assume the primary role during a failure. The formulas provided in Configuring Memory for WarehousePG for configuring segment host memory include a factor for the maximum number of primary hosts on any one segment during a failure. The arrangement of mirrors on the segment hosts affects this factor and how the system will respond during a failure. See Segment Mirroring Configurations for a discussion of segment mirroring options.

Best Practices

- Set up mirrors for all segments.
- Locate primary segments and their mirrors on different hosts to protect against host failure.
- Mirrors can be on a separate set of hosts or co-located on hosts with primary segments.
- Set up monitoring to send notifications in a system monitoring application or by email when a primary segment fails.
- Recover failed segments promptly, using the `gprecoverseg` utility, to restore redundancy and return the system to optimal balance.

Dual Clusters

For some use cases, an additional level of redundancy can be provided by maintaining two WarehousePG clusters that store the same data. The decision to implement dual clusters should be made with business requirements in mind.

There are two recommended methods for keeping the data synchronized in a dual cluster configuration. The first method is called Dual ETL. ETL (extract, transform, and load) is the common data warehousing process of cleansing, transforming, validating, and loading data into a data warehouse. With Dual ETL, the ETL processes are performed twice, in parallel on each cluster, and validated each time. Dual ETL provides for a complete standby cluster with the same data. It also provides the capability to query the data on both clusters, doubling the processing throughput. The application can take advantage of both clusters as needed and also ensure that the ETL is successful and validated on both sides.

The second mechanism for maintaining dual clusters is backup and restore. The data is backedup on the primary cluster, then the backup is replicated to and restored on the second cluster. The backup and restore mechanism has higher latency than Dual ETL, but requires less application logic to be developed. Backup and restore is ideal for use cases where data modifications and ETL are done daily or less frequently.

Best Practices

- Consider a Dual Cluster configuration to provide an additional level of redundancy and additional query processing throughput.

Backup and Restore

Backups are recommended for WarehousePG databases unless the data in the database can be easily and cleanly regenerated from source data. Backups protect from operational, software, or hardware errors.

The `gpbackup` utility makes backups in parallel across the segments, so that backups scale as the cluster grows in hardware size.

A backup strategy must consider where the backups will be written and where they will be stored. Backups can be taken to the local cluster disks, but they should not be stored there permanently. If the database and its backup are on the same storage, they can be lost simultaneously. The backup also occupies space that could be used for database storage or operations. After performing a local backup, the files should be copied to a safe, off-cluster location.

An alternative is to back up directly to an NFS mount. If each host in the cluster has an NFS mount, the backups can be written directly to NFS storage. A scale-out NFS solution is recommended to ensure that backups do not bottleneck on the IO throughput of the NFS device. Dell PowerScale (Isilon) is an example of this type of solution and can scale alongside the WarehousePG cluster.

Best Practices

- Back up WarehousePGs regularly unless the data is easily restored from sources.
- Use the `gpbackup` command to specify only the schema and tables that you want backed up. See the `gpbackup` reference for more information.
- `gpbackup` places `SHARED ACCESS` locks on the set of tables to back up. Backups with fewer tables are more efficient for selectively restoring schemas and tables, since `gprestore` does not have to search through the entire database.
- If backups are saved to local cluster storage, move the files to a safe, off-cluster location when the backup is complete. Backup files and database files that reside on the same storage can be lost simultaneously.
- If backups are saved to NFS mounts, use a scale-out NFS solution such as Dell PowerScale (Isilon) to prevent IO bottlenecks.

Detecting Failed Coordinator and Segment Instances

Recovering from system failures requires intervention from a system administrator, even when the system detects a failure and activates a standby for the failed component. In each case, the failed component must be replaced or recovered to restore full redundancy. Until the failed component is recovered, the active component lacks a standby, and the system may not be performing optimally. For these reasons, it is important to perform recovery operations promptly. Constant system monitoring ensures that administrators are aware of failures that demand their attention.

The WarehousePG server `ftsprobe` subprocess handles fault detection. `ftsprobe` connects to and scans all segments and database processes at intervals that you can configure with the `gp_fts_probe_interval` configuration parameter. If `ftsprobe` cannot connect to a segment, it marks the segment "down" in the WarehousePG cluster catalog. The segment remains down until an administrator runs the `gprecoverseg` recovery utility.

Best Practices

- Run the `gpstate` utility to see the overall state of the WarehousePG cluster.

Additional Information

WarehousePG Administrator Guide:

- Monitoring a WarehousePG cluster
- Recovering from Segment Failures

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WarehousePG Utility Guide:

- gpstate - view state of the WarehousePG cluster
- gprecoverseg - recover a failed segment
- gpactivatestandby - make the standby coordinator the active coordinator

RDBMS MIB Specification

Segment Mirroring Configurations

Segment mirroring allows database queries to fail over to a backup segment if the primary segment fails or becomes unavailable. Mirroring is required for production supported WarehousePG clusters.

A primary segment and its mirror must be on different hosts to ensure high availability. Each host in a WarehousePG cluster has the same number of primary segments and mirror segments. Multi-homed hosts should have the same numbers of primary and mirror segments on each interface. This ensures that segment hosts and network resources are equally loaded when all primary segments are operational and brings the most resources to bear on query processing.

When a segment becomes unavailable, its mirror segment on another host becomes the active primary and processing continues. The additional load on the host creates skew and degrades performance, but should allow the system to continue. A database query is not complete until all segments return results, so a single host with an additional active primary segment has the same effect as adding an additional primary segment to every host in the cluster.

The least amount of performance degradation in a failover scenario occurs when no host has more than one mirror assuming the primary role. If multiple segments or hosts fail, the amount of degradation is determined by the host or hosts with the largest number of mirrors assuming the primary role. Spreading a host's mirrors across the remaining hosts minimizes degradation when any single host fails.

It is important, too, to consider the cluster's tolerance for multiple host failures and how to maintain a mirror configuration when expanding the cluster by adding hosts. There is no mirror configuration that is ideal for every situation.

You can allow WarehousePG to arrange mirrors on the hosts in the cluster using one of two standard configurations, or you can design your own mirroring configuration.

The two standard mirroring arrangements are *group mirroring* and *spread mirroring*:

- **Group mirroring** — Each host mirrors another host's primary segments. This is the default for gpinitsystem and gpaddmirrors.
- **Spread mirroring** — Mirrors are spread across the available hosts. This requires that the number of hosts in the cluster is greater than the number of segments per host.

You can design a custom mirroring configuration and use the WarehousePG `gpaddmirrors` or gpmovemirrors utilities to set up the configuration.

Block mirroring is a custom mirror configuration that divides hosts in the cluster into equally sized blocks and distributes mirrors evenly to hosts within the block. If a primary segment fails, its mirror on another host within the same block becomes the active primary. If a segment host fails, mirror segments on each of the other hosts in the block become active.

The following sections compare the group, spread, and block mirroring configurations.

Group Mirroring

Group mirroring is easiest to set up and is the default WarehousePG mirroring configuration. It is least expensive to expand, since it can be done by adding as few as two hosts. There is no need to move mirrors after expansion to maintain a consistent mirror configuration.

The following diagram shows a group mirroring configuration with eight primary segments on four hosts.

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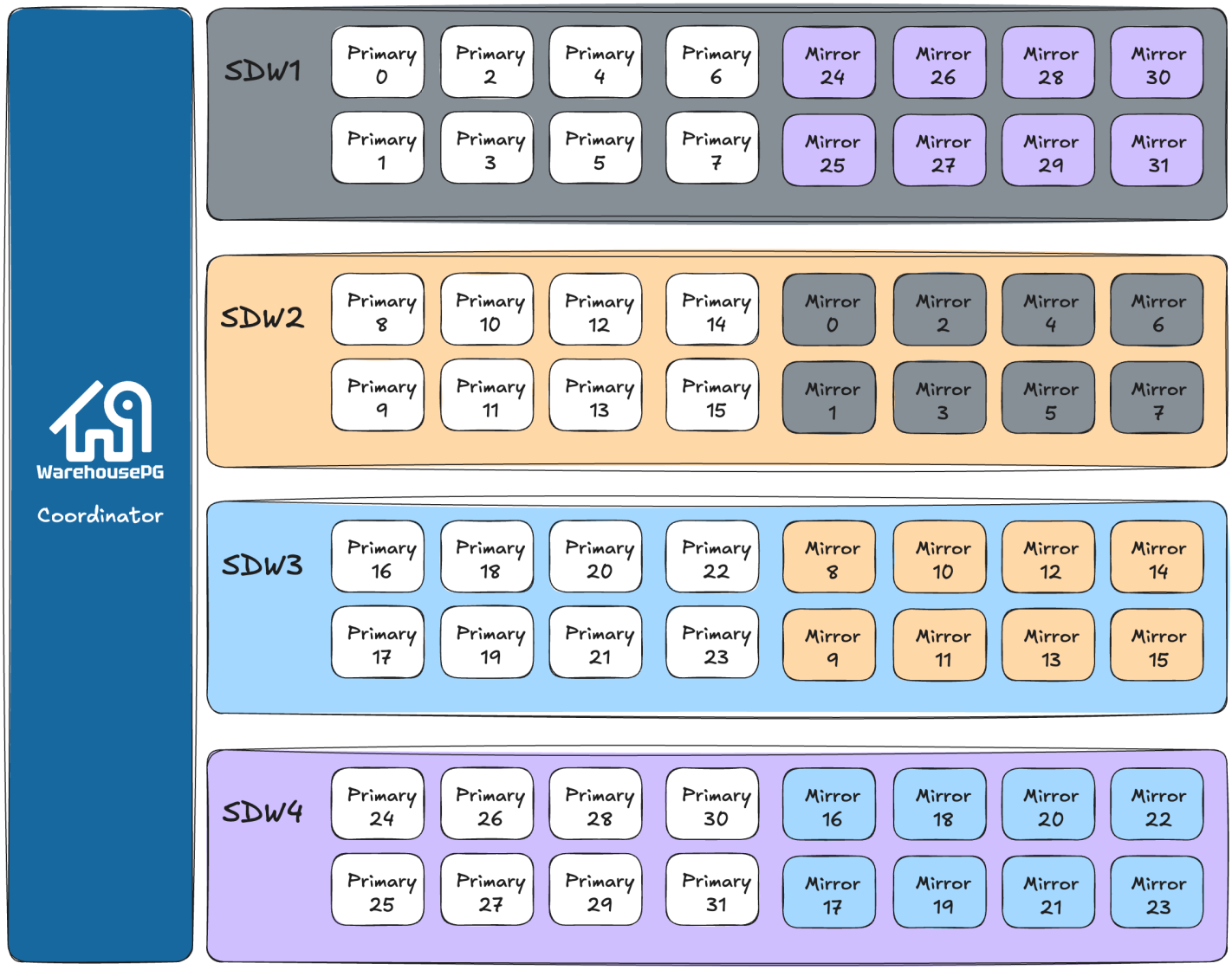

WHPG Group Mirroring

Unless both the primary and mirror of the same segment instance fail, up to half of your hosts can fail and the cluster will continue to run as long as resources (CPU, memory, and IO) are sufficient to meet the needs.

Any host failure will degrade performance by half or more because the host with the mirrors will have twice the number of active primaries. If your resource utilization is normally greater than 50%, you will have to adjust your workload until the failed host is recovered or replaced. If you normally run at less than 50% resource utilization the cluster can continue to operate at a degraded level of performance until the failure is corrected.

Spread Mirroring

With spread mirroring, mirrors for each host's primary segments are spread across as many hosts as there are segments per host. Spread mirroring is easy to set up when the cluster is initialized, but requires that the cluster have at least one more host than there are segments per host.

The following diagram shows the spread mirroring configuration for a cluster with three primaries on four hosts.

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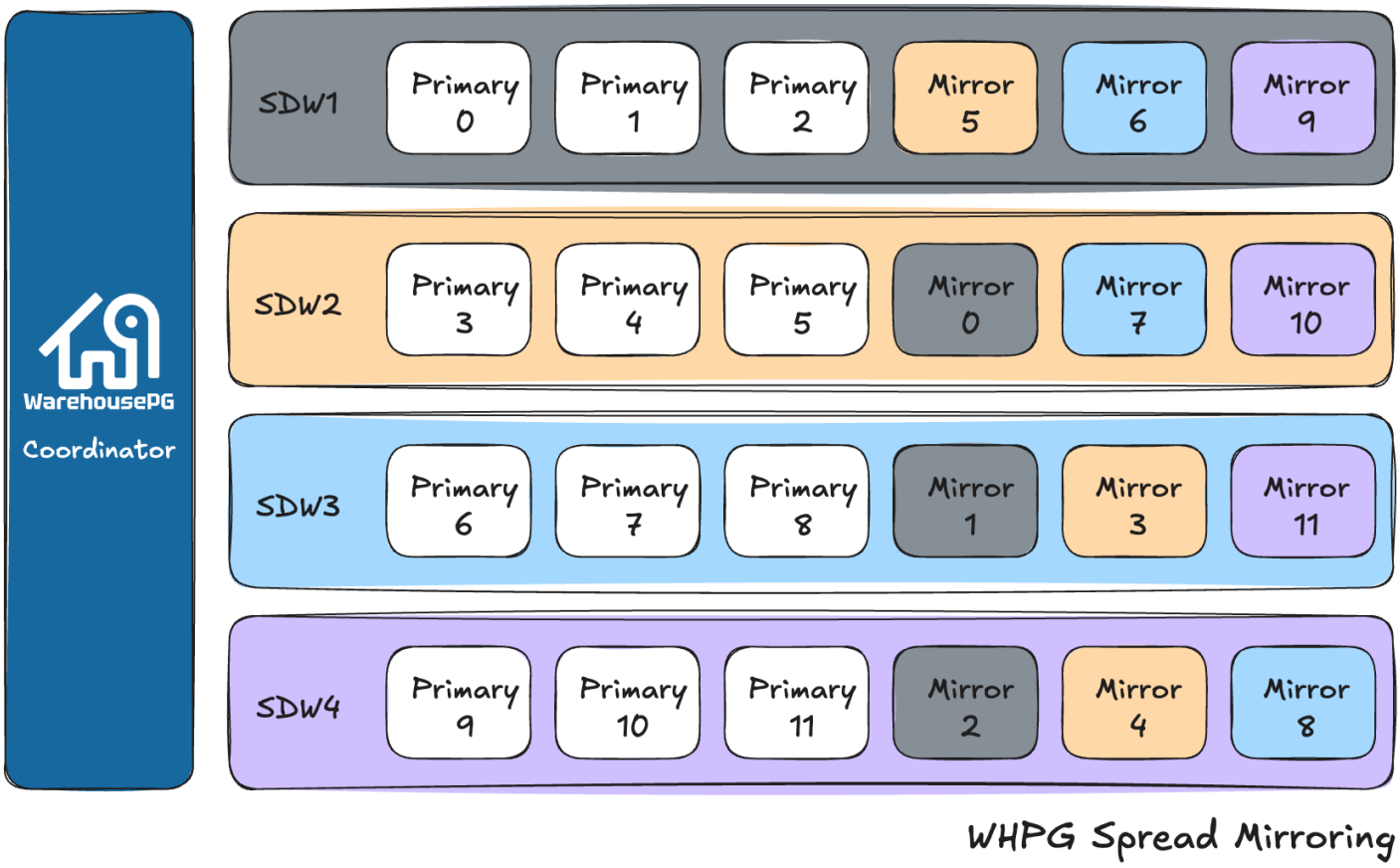

Expanding a cluster with spread mirroring requires more planning and may take more time. You must either add a set of hosts equal to the number of primaries per host plus one, or you can add two nodes in a group mirroring configuration and, when the expansion is complete, move mirrors to recreate the spread mirror configuration.

Spread mirroring has the least performance impact for a single failed host because each host's mirrors are spread across the maximum number of hosts. Load is increased by 1/*Nth*, where *N* is the number of primaries per host. Spread mirroring is, however, the most likely configuration to have a catastrophic failure if two or more hosts fail simultaneously.

Block Mirroring

With block mirroring, nodes are divided into blocks, for example a block of four or eight hosts, and the mirrors for segments on each host are placed on other hosts within the block. Depending on the number of hosts in the block and the number of primary segments per host, each host maintains more than one mirror for each other host's segments.

The following diagram shows a single block mirroring configuration for a block of four hosts, each with eight primary segments:

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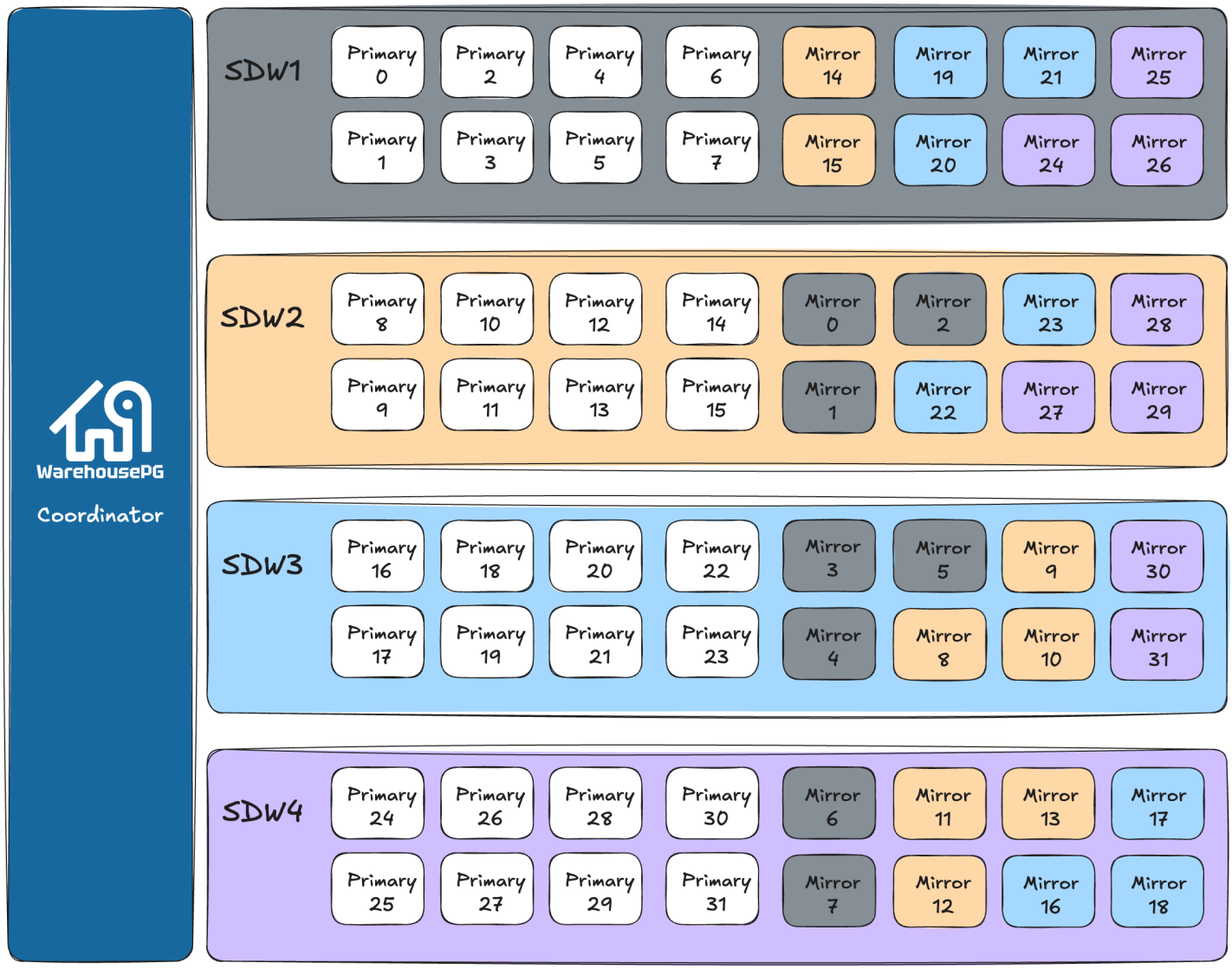

WHPG Block Mirroring

If there are eight hosts, an additional four-host block is added with the mirrors for primary segments 32 through 63 set up in the same pattern.

A cluster with block mirroring is easy to expand because each block is a self-contained primary mirror group. The cluster is expanded by adding one or more blocks. There is no need to move mirrors after expansion to maintain a consistent mirror setup. This configuration is able to survive multiple host failures as long as the failed hosts are in different blocks.

Because each host in a block has multiple mirror instances for each other host in the block, block mirroring has a higher performance impact for host failures than spread mirroring, but a lower impact than group mirroring. The expected performance impact varies by block size and primary segments per node. As with group mirroring, if the resources are available, performance will be negatively impacted but the cluster will remain available. If resources are insufficient to accommodate the added load you must reduce the workload until the failed node is replaced.

Implementing Block Mirroring

Block mirroring is not one of the automatic options WarehousePG offers when you set up or expand a cluster. To use it, you must create your own configuration.

For a new WarehousePG cluster, you can initialize the cluster without mirrors, and then run `gpaddmirrors -i mirror_config_file` with a custom mirror configuration file to create the mirrors for each block. You must create the file system locations for the mirror segments before you run `gpaddmirrors`. See the `gpaddmirrors` reference page in the *WarehousePG Management Utility Guide* for details.

If you expand a system that has block mirroring or you want to implement block mirroring at the same time you expand a cluster, it is recommended that you complete the expansion first, using the default grouping mirror configuration, and then use the `gpmovemirrors` utility to move mirrors into the block configuration.

To implement block mirroring with an existing system that has a different mirroring scheme, you must first determine the desired location for each mirror according to your block configuration, and then determine which of the existing mirrors must be relocated. Follow these steps:

1. Run the following query to find the current locations of the primary and mirror segments:

   ```
   SELECT dbid, content, role, port, hostname, datadir FROM gp_segment_configuration WHERE content > -1 ;
   ```

   The `gp_segment_configuration` system catalog table contains the current segment configuration.

2. Create a list with the current mirror location and the desired block mirroring location, then remove any mirrors from the list that are already on the correct host.

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3. Create an input file for the `gpmovemirrors` utility with an entry for each mirror that must be moved.

   The `gpmovemirrors` input file has the following format:

   ```
   old_address|port|data_dir new_address|port|data_dir
   ```

   Where `old_address` is the host name or IP address of the segment host, port is the communication port, and `data_dir` is the segment instance data directory.

   The following example `gpmovemirrors` input file specifies three mirror segments to move.

   ```
   sdw2|50001|/data2/mirror/gpseg1 sdw3|50001|/data/mirror/gpseg1
   sdw2|50001|/data2/mirror/gpseg2 sdw4|50001|/data/mirror/gpseg2
   sdw3|50001|/data2/mirror/gpseg3 sdw1|50001|/data/mirror/gpseg3
   ```

4. Run `gpmovemirrors` with a command like the following:

   ```
   gpmovemirrors -i mirror_config_file
   ```

The `gpmovemirrors` utility validates the input file, calls `gprecoverseg` to relocate each specified mirror, and removes the original mirror. It creates a backout configuration file which can be used as input to `gpmovemirrors` to undo the changes that were made. The backout file has the same name as the input file, with the suffix `_backout_timestamp` added.

See the *WarehousePG Management Utility Reference* for complete information about the `gpmovemirrors` utility.

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7 WarehousePG reference guide

Reference information for WarehousePG clusters including SQL commands, system catalogs, environment variables, server configuration parameters, character set support, datatypes, and WarehousePG extensions.

- SQL Commands
- Data Types
- Summary of Built-in Functions
- Additional Supplied Modules
- Character Set Support
- Server Configuration Parameters
- Database Utilities
- System Catalogs
- The gp_toolkit Administrative Schema
- Server Programmatic Interfaces
- SQL Features, Reserved and Key Words, and Compliance

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7.1 SQL Commands

The following SQL commands are available in WarehousePG:

- ABORT
- ALTER AGGREGATE
- ALTER COLLATION
- ALTER CONVERSION
- ALTER DATABASE
- ALTER DEFAULT PRIVILEGES
- ALTER DOMAIN
- ALTER EXTENSION
- ALTER EXTERNAL TABLE
- ALTER FOREIGN DATA WRAPPER
- ALTER FOREIGN TABLE
- ALTER FUNCTION
- ALTER GROUP
- ALTER INDEX
- ALTER LANGUAGE
- ALTER MATERIALIZED VIEW
- ALTER OPERATOR
- ALTER OPERATOR CLASS
- ALTER OPERATOR FAMILY
- ALTER POLICY
- ALTER PROCEDURE
- ALTER PROTOCOL
- ALTER RESOURCE GROUP
- ALTER RESOURCE QUEUE
- ALTER ROLE
- ALTER ROUTINE
- ALTER RULE
- ALTER SCHEMA
- ALTER SEQUENCE
- ALTER SERVER
- ALTER STATISTICS
- ALTER TABLE
- ALTER TABLESPACE
- ALTER TEXT SEARCH CONFIGURATION
- ALTER TEXT SEARCH DICTIONARY
- ALTER TEXT SEARCH PARSER
- ALTER TEXT SEARCH TEMPLATE
- ALTER TYPE
- ALTER USER
- ALTER USER MAPPING
- ALTER VIEW
- ANALYZE
- BEGIN
- CALL
- CHECKPOINT
- CLOSE
- CLUSTER
- COMMENT
- COMMIT
- COPY
- CREATE ACCESS METHOD
- CREATE AGGREGATE
- CREATE CAST
- CREATE COLLATION
- CREATE CONVERSION
- CREATE DATABASE
- CREATE DOMAIN
- CREATE EXTENSION
- CREATE EXTERNAL TABLE
- CREATE FOREIGN DATA WRAPPER
- CREATE FOREIGN TABLE
- CREATE FUNCTION
- CREATE GROUP
- CREATE INDEX
- CREATE LANGUAGE
- CREATE MATERIALIZED VIEW
- CREATE OPERATOR
- CREATE OPERATOR CLASS
- CREATE OPERATOR FAMILY
- CREATE POLICY
- CREATE PROCEDURE
- CREATE PROTOCOL
- CREATE RESOURCE GROUP
- CREATE RESOURCE QUEUE
- CREATE ROLE
- CREATE RULE
- CREATE SCHEMA
- CREATE SEQUENCE
- CREATE SERVER
- CREATE STATISTICS
- CREATE TABLE
- CREATE TABLE AS
- CREATE TABLESPACE
- CREATE TEXT SEARCH CONFIGURATION
- CREATE TEXT SEARCH DICTIONARY
- CREATE TEXT SEARCH PARSER
- CREATE TEXT SEARCH TEMPLATE
- CREATE TRANSFORM
- CREATE TYPE
- CREATE USER
- CREATE USER MAPPING
- CREATE VIEW
- DEALLOCATE
- DECLARE
- DELETE
- DISCARD
- DO

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- DROP ACCESS METHOD
- DROP AGGREGATE
- DROP CAST
- DROP COLLATION
- DROP CONVERSION
- DROP DATABASE
- DROP DOMAIN
- DROP EXTENSION
- DROP EXTERNAL TABLE
- DROP FOREIGN DATA WRAPPER
- DROP FOREIGN TABLE
- DROP FUNCTION
- DROP GROUP
- DROP INDEX
- DROP LANGUAGE
- DROP MATERIALIZED VIEW
- DROP OPERATOR
- DROP OPERATOR CLASS
- DROP OPERATOR FAMILY
- DROP OWNED
- DROP POLICY
- DROP PROCEDURE
- DROP PROTOCOL
- DROP RESOURCE GROUP
- DROP RESOURCE QUEUE
- DROP ROLE
- DROP ROUTINE
- DROP RULE
- DROP SCHEMA
- DROP SEQUENCE
- DROP SERVER
- DROP STATISTICS
- DROP TABLE
- DROP TABLESPACE
- DROP TEXT SEARCH CONFIGURATION
- DROP TEXT SEARCH DICTIONARY
- DROP TEXT SEARCH PARSER
- DROP TEXT SEARCH TEMPLATE
- DROP TRANSFORM
- DROP TYPE
- DROP USER
- DROP USER MAPPING
- DROP VIEW
- END
- EXECUTE
- EXPLAIN
- FETCH
- GRANT
- IMPORT FOREIGN SCHEMA
- INSERT
- LISTEN
- LOAD
- LOCK
- MOVE
- NOTIFY
- PREPARE
- REASSIGN OWNED
- REFRESH MATERIALIZED VIEW
- REINDEX
- RELEASE SAVEPOINT
- RESET
- RETRIEVE
- REVOKE
- ROLLBACK
- ROLLBACK TO SAVEPOINT
- SAVEPOINT
- SELECT
- SELECT INTO
- SET
- SET CONSTRAINTS
- SET ROLE
- SET SESSION AUTHORIZATION
- SET TRANSACTION
- SHOW
- START TRANSACTION
- TRUNCATE
- UNLISTEN
- UPDATE
- VACUUM
- VALUES

Parent topic: WarehousePG Reference Guide

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7.1.1 ABORT

Terminates the current transaction.

Synopsis

```
ABORT [WORK | TRANSACTION] [AND [NO] CHAIN]
```

Description

`ABORT` rolls back the current transaction and causes all the updates made by the transaction to be discarded. This command is identical in behavior to the standard SQL commandROLLBACK, and is present only for historical reasons.

Parameters

WORK TRANSACTION Optional key words. They have no effect.

AND CHAIN If `AND CHAIN` is specified, a new transaction is immediately started with the same transaction characteristics (see SET TRANSACTION) as the just finished one. Otherwise, no new transaction is started.

Notes

Use COMMIT to successfully terminate a transaction.

Issuing `ABORT` outside of a transaction block emits a warning and otherwise has no effect.

Examples

To terminate all changes:

```
ABORT;
```

Compatibility

This command is a WarehousePG extension present for historical reasons. `ROLLBACK` is the equivalent standard SQL command.

See Also

BEGIN, COMMIT, ROLLBACK

Parent topic: SQL Commands

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7.1.2 ALTER AGGREGATE

Changes the definition of an aggregate function

Synopsis

```
ALTER AGGREGATE <name> ( <aggregate_signature> )  RENAME TO <new_name>

ALTER AGGREGATE <name> ( <aggregate_signature> )
                 OWNER TO { <new_owner> | CURRENT_USER | SESSION_USER }

ALTER AGGREGATE <name> ( <aggregate_signature> ) SET SCHEMA <new_schema>

where <aggregate_signature> is:

* |
[ <argmode> ] [ <argname> ] <argtype> [ , ... ] |
[ [ <argmode> ] [ <argname> ] <argtype> [ , ... ] ] ORDER BY [ <argmode> ] [ <argname> ] <argtype> [ , ... ]
```

Description

`ALTER AGGREGATE` changes the definition of an aggregate function.

You must own the aggregate function to use `ALTER AGGREGATE`. To change the schema of an aggregate function, you must also have `CREATE` privilege on the new schema. To alter the owner, you must also be a direct or indirect member of the new owning role, and that role must have `CREATE` privilege on the aggregate function's schema. (These restrictions enforce that altering the owner does not do anything you could not do by dropping and recreating the aggregate function. However, a superuser can alter ownership of any aggregate function anyway.)

Parameters

name The name (optionally schema-qualified) of an existing aggregate function.

argmode The mode of an argument: `IN` or `VARIADIC`. If omitted, the default is `IN`.

argname The name of an argument. Note that `ALTER AGGREGATE` does not actually pay any attention to argument names, since only the argument data types are needed to determine the aggregate function's identity.

argtype An input data type on which the aggregate function operates. To reference a zero-argument aggregate function, write `*` in place of the list of argument specifications To reference an ordered-set aggregate function, write `ORDER BY` between the direct and aggregated argument specifications.

new_name The new name of the aggregate function.

new_owner The new owner of the aggregate function.

new_schema The new schema for the aggregate function.

Notes

The recommended syntax for referencing an ordered-set aggregate is to write `ORDER BY` between the direct and aggregated argument specifications, in the same style as inCREATE AGGREGATE. However, it will also work to omit `ORDER BY` and just run the direct and aggregated argument specifications into a single list. In this abbreviated form, if `VARIADIC "any"` was used in both the direct and aggregated argument lists, write `VARIADIC "any"` only once.

Examples

To rename the aggregate function `myavg` for type `integer` to `my_average`:

```
ALTER AGGREGATE myavg(integer) RENAME TO my_average;
```

To change the owner of the aggregate function `myavg` for type `integer` to `joe`:

```
ALTER AGGREGATE myavg(integer) OWNER TO joe;
```

To move the ordered-set aggregate `mypercentile` with direct argument of type `float8` and aggregated argument of type `integer` into schema `myschema`:

```
ALTER AGGREGATE mypercentile(float8 ORDER BY integer) SET SCHEMA myschema;
```

This will work too:

```
ALTER AGGREGATE mypercentile(float8, integer) SET SCHEMA myschema;
```

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Compatibility

There is no `ALTER AGGREGATE` statement in the SQL standard.

See Also

CREATE AGGREGATE, DROP AGGREGATE

Parent topic: SQL Commands

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7.1.3 ALTER COLLATION

Changes the definition of a collation.

Synopsis

```
ALTER COLLATION <name> REFRESH VERSION

ALTER COLLATION <name> RENAME TO <new_name>
ALTER COLLATION <name> OWNER TO { <new_owner> | CURRENT_USER | SESSION_USER }
ALTER COLLATION <name> SET SCHEMA <new_schema>
```

Description

`ALTER COLLATION` changes the definition of a collation.

You must own the collation to use `ALTER COLLATION`. To alter the owner, you must also be a direct or indirect member of the new owning role, and that role must have `CREATE` privilege on the collation's schema. (These restrictions enforce that altering the owner doesn't do anything you couldn't do by dropping and recreating the collation. However, a superuser can alter ownership of any collation anyway.)

Parameters

name The name (optionally schema-qualified) of an existing collation.

new_name The new name of the collation.

new_owner The new owner of the collation.

new_schema The new schema for the collation.

REFRESH VERSION Update the collation's version. See the Notes below.

Notes

When using collations provided by the ICU library, the ICU-specific version of the collator is recorded in the system catalog when the collation object is created. When the collation is used, the current version is checked against the recorded version, and a warning is issued when there is a mismatch, for example:

```
WARNING:  collation "xx-x-icu" has version mismatch
DETAIL:  The collation in the database was created using version 1.2.3.4, but the operating system provides version 2.3.4.5.
HINT:  Rebuild all objects affected by this collation and run ALTER COLLATION pg_catalog."xx-x-icu" REFRESH VERSION, or build PostgreSQL with the right library
version.
```

A change in collation definitions can lead to corrupt indexes and other problems because the database system relies on stored objects having a certain sort order. Generally, this should be avoided, but it can happen in legitimate circumstances, such as when using `pg_upgrade` to upgrade to server binaries linked with a newer version of ICU. When this happens, all objects depending on the collation should be rebuilt, for example, using `REINDEX`. When that is done, the collation version can be refreshed using the command `ALTER COLLATION ... REFRESH VERSION`. This will update the system catalog to record the current collator version and will make the warning go away. Note that this does not actually check whether all affected objects have been rebuilt correctly.

The following query can be used to identify all collations in the current database that need to be refreshed and the objects that depend on them:

```
SELECT pg_describe_object(refclassid, refobjid, refobjsubid) AS "Collation",
       pg_describe_object(classid, objid, objsubid) AS "Object"
  FROM pg_depend d JOIN pg_collation c
       ON refclassid = 'pg_collation'::regclass AND refobjid = c.oid
  WHERE c.collversion <> pg_collation_actual_version(c.oid)
  ORDER BY 1, 2;
```

Examples

To rename the collation de_DE to `german`:

```
ALTER COLLATION "de_DE" RENAME TO german;
```

To change the owner of the collation `en_US` to `joe`:

```
ALTER COLLATION "en_US" OWNER TO joe;
```

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Compatibility

There is no `ALTER COLLATION` statement in the SQL standard.

See Also

CREATE COLLATION, DROP COLLATION

Parent topic: SQL Commands

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7.1.4 ALTER CONVERSION

Changes the definition of a conversion.

Synopsis

```
ALTER CONVERSION <name> RENAME TO <new_name>

ALTER CONVERSION <name> OWNER TO { <new_owner> | CURRENT_USER | SESSION_USER }

ALTER CONVERSION <name> SET SCHEMA <new_schema>
```

Description

`ALTER CONVERSION` changes the definition of a conversion.

You must own the conversion to use `ALTER CONVERSION`. To alter the owner, you must also be a direct or indirect member of the new owning role, and that role must have `CREATE` privilege on the conversion's schema. (These restrictions enforce that altering the owner does not do anything you could not do by dropping and recreating the conversion. However, a superuser can alter ownership of any conversion anyway.)

Parameters

name The name (optionally schema-qualified) of an existing conversion.

new_name The new name of the conversion.

new_owner The new owner of the conversion.

new_schema The new schema for the conversion.

Examples

To rename the conversion `iso_8859_1_to_utf8` to `latin1_to_unicode`:

```
ALTER CONVERSION iso_8859_1_to_utf8 RENAME TO latin1_to_unicode;
```

To change the owner of the conversion `iso_8859_1_to_utf8` to `joe`:

```
ALTER CONVERSION iso_8859_1_to_utf8 OWNER TO joe;
```

Compatibility

There is no `ALTER CONVERSION` statement in the SQL standard.

See Also

CREATE CONVERSION, DROP CONVERSION

Parent topic: SQL Commands

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7.1.5 ALTER DATABASE

Changes the attributes of a database.

Synopsis

```
ALTER DATABASE <name> [ [WITH] <option> [ ... ]  ]

where <option> can be:

    ALLOW_CONNECTIONS <allowconn>
    CONNECTION LIMIT <connlimit>
    IS_TEMPLATE <istemplate>

ALTER DATABASE <name> RENAME TO <new_name>

ALTER DATABASE <name> OWNER TO { <new_owner> | CURRENT_USER | SESSION_USER }

ALTER DATABASE <name> SET TABLESPACE <new_tablespace>

ALTER DATABASE <name> SET <configuration_parameter> { TO | = } { <value> | DEFAULT }
ALTER DATABASE <name> SET <configuration_parameter> FROM CURRENT
ALTER DATABASE <name> RESET <configuration_parameter>
ALTER DATABASE <name> RESET ALL
```

Description

`ALTER DATABASE` changes the attributes of a database.

The first form changes the per-database settings. (See below for details.) Only the database owner or a superuser can change these settings.

The second form changes the name of the database. Only the database owner or a superuser can rename a database; non-superuser owners must also have the `CREATEDB` privilege. You cannot rename the current database. Connect to a different database first.

The third form changes the owner of the database. To alter the owner, you must own the database and also be a direct or indirect member of the new owning role, and you must have the `CREATEDB` privilege. (Note that superusers have all these privileges automatically.)

The fourth form changes the default tablespace of the database. Only the database owner or a superuser can do this; you must also have create privilege for the new tablespace. This command physically moves any tables or indexes in the database's old default tablespace to the new tablespace. The new default tablespace must be empty for this database, and no one can be connected to the database. Note that tables and indexes in non-default tablespaces are not affected.

The remaining forms change the session default for a configuration parameter for a WarehousePG. Whenever a new session is subsequently started in that database, the specified value becomes the session default value. The database-specific default overrides whatever setting is present in the server configuration file (`postgresql.conf`). Only the database owner or a superuser can change the session defaults for a database. Certain parameters cannot be set this way, or can only be set by a superuser.

Parameters

name The name of the database whose attributes are to be altered.

allowconn If `false` , then no one can connect to this database.

connlimit The maximum number of concurrent connections allowed to this database on the coordinator. The default is `-1` , no limit. WarehousePG superusers are exempt from this limit.

istemplate If `true` , then this database can be cloned by any user with `CREATEDB` privileges; if `false` , then only superusers or the owner of the database can clone it. Note that template databases cannot be dropped.

new_name The new name of the database.

new_owner The new owner of the database.

new_tablespace The new default tablespace of the database. This form of the command cannot be executed inside a transaction block.

configuration_parameter value Set this database's session default for the specified configuration parameter to the given value. If value is `DEFAULT` or, equivalently, `RESET` is used, the database-specific setting is removed, so the system-wide default setting will be inherited in new sessions. Use `RESET ALL` to clear all database-specific settings. `SET FROM CURRENT` saves the session's current value of the parameter as the database-specific value. SeeSET and Server Configuration Parameters for more information about allowed parameter names and values.

Notes

It is also possible to tie a session default to a specific role rather than to a database; seeALTER ROLE. Role-specific settings override database-specific ones if there is a conflict.

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Examples

To disable index scans by default in the `test` database:

```
ALTER DATABASE test SET enable_indexscan TO off;
```

To set the default schema search path for the `mydatabase` database:

```
ALTER DATABASE mydatabase SET search_path TO myschema, public, pg_catalog;
```

Compatibility

The `ALTER DATABASE` statement is a WarehousePG extension.

See Also

CREATE DATABASE, DROP DATABASE, SET, CREATE TABLESPACE

Parent topic: SQL Commands

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7.1.6 ALTER DEFAULT PRIVILEGES

Changes default access privileges.

Synopsis

```
ALTER DEFAULT PRIVILEGES
    [ FOR { ROLE | USER } <target_role> [, ...] ]
    [ IN SCHEMA <schema_name> [, ...] ]
    <abbreviated_grant_or_revoke>

where <abbreviated_grant_or_revoke> is one of:

GRANT { { SELECT | INSERT | UPDATE | DELETE | TRUNCATE | REFERENCES | TRIGGER }
    [, ...] | ALL [ PRIVILEGES ] }
    ON TABLES
    TO { [ GROUP ] <role_name> | PUBLIC } [, ...] [ WITH GRANT OPTION ]

GRANT { { USAGE | SELECT | UPDATE }
    [, ...] | ALL [ PRIVILEGES ] }
    ON SEQUENCES
    TO { [ GROUP ] <role_name> | PUBLIC } [, ...] [ WITH GRANT OPTION ]

GRANT { EXECUTE | ALL [ PRIVILEGES ] }
    ON { FUNCTIONS | ROUTINES }
    TO { [ GROUP ] <role_name> | PUBLIC } [, ...] [ WITH GRANT OPTION ]

GRANT { USAGE | ALL [ PRIVILEGES ] }
    ON TYPES
    TO { [ GROUP ] <role_name> | PUBLIC } [, ...] [ WITH GRANT OPTION ]

GRANT { USAGE | CREATE | ALL [ PRIVILEGES ] }
    ON SCHEMAS
    TO { [ GROUP ] <role_name> | PUBLIC } [, ...] [ WITH GRANT OPTION ]

REVOKE [ GRANT OPTION FOR ]
    { { SELECT | INSERT | UPDATE | DELETE | TRUNCATE | REFERENCES | TRIGGER }
    [, ...] | ALL [ PRIVILEGES ] }
    ON TABLES
    FROM { [ GROUP ] <role_name> | PUBLIC } [, ...]
    [ CASCADE | RESTRICT ]

REVOKE [ GRANT OPTION FOR ]
    { { USAGE | SELECT | UPDATE }
    [, ...] | ALL [ PRIVILEGES ] }
    ON SEQUENCES
    FROM { [ GROUP ] <role_name> | PUBLIC } [, ...]
    [ CASCADE | RESTRICT ]

REVOKE [ GRANT OPTION FOR ]
    { EXECUTE | ALL [ PRIVILEGES ] }
    ON { FUNCTIONS | ROUTINES }
    FROM { [ GROUP ] <role_name> | PUBLIC } [, ...]
    [ CASCADE | RESTRICT ]

REVOKE [ GRANT OPTION FOR ]
    { USAGE | ALL [ PRIVILEGES ] }
    ON TYPES
    FROM { [ GROUP ] <role_name> | PUBLIC } [, ...]
    [ CASCADE | RESTRICT ]

REVOKE [ GRANT OPTION FOR ]
    { USAGE | CREATE | ALL [ PRIVILEGES ] }
    ON SCHEMAS
    FROM { [ GROUP ] <role_name> | PUBLIC } [, ...]
    [ CASCADE | RESTRICT ]
```

Description

`ALTER DEFAULT PRIVILEGES` allows you to set the privileges that will be applied to objects created in the future. (It does not affect privileges assigned to already-existing objects.) Currently, only the privileges for schemas, tables (including views and foreign tables), sequences, functions, and types (including domains) can be altered. For this command, functions include aggregates and procedures. The words `FUNCTIONS` and `ROUTINES` are equivalent in this command. (`ROUTINES` is preferred going forward as the standard term for functions and procedures taken together. In earlier WarehousePG releases, only the word `FUNCTIONS` was allowed. It is not possible to set default privileges for functions and procedures separately.)

You can change default privileges only for objects that will be created by yourself or by roles that you are a member of. The privileges can be set globally (i.e., for all objects created in the current database), or just for objects created in specified schemas.

As explained under GRANT, the default privileges for any object type normally grant all grantable permissions to the object owner, and may grant some privileges to `PUBLIC` as well. However, this behavior can be changed by altering the global default privileges with `ALTER DEFAULT PRIVILEGES` .

Default privileges that are specified per-schema are added to whatever the global default privileges are for the particular object type. This means you cannot revoke privileges per-schema if they are granted globally (either by default, or according to a previous `ALTER DEFAULT PRIVILEGES` command that did not specify a schema). Per-schema `REVOKE` is only useful to reverse the effects of a previous per-schema `GRANT` .

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Parameters

target_role The name of an existing role of which the current role is a member. If `FOR ROLE` is omitted, the current role is assumed.

schema_name The name of an existing schema. If specified, the default privileges are altered for objects later created in that schema. If `IN SCHEMA` is omitted, the global default privileges are altered. `IN SCHEMA` is not allowed when setting privileges for schemas, since schemas can't be nested.

role_name The name of an existing role to grant or revoke privileges for. This parameter, and all the other parameters in abbreviated_grant_or_revoke, act as described underGRANT or REVOKE, except that one is setting permissions for a whole class of objects rather than specific named objects.

Notes

Use psql's `\ddp` command to obtain information about existing assignments of default privileges. The meaning of the privilege values is the same as explained for `\dp` under GRANT.

If you wish to drop a role for which the default privileges have been altered, it is necessary to reverse the changes in its default privileges or use `DROP OWNED BY` to get rid of the default privileges entry for the role.

Examples

Grant SELECT privilege to everyone for all tables (and views) you subsequently create in schema `myschema`, and allow role `webuser` to INSERT into them too:

```
ALTER DEFAULT PRIVILEGES IN SCHEMA myschema GRANT SELECT ON TABLES TO PUBLIC;
ALTER DEFAULT PRIVILEGES IN SCHEMA myschema GRANT INSERT ON TABLES TO webuser;
```

Undo the above, so that subsequently-created tables won't have any more permissions than normal:

```
ALTER DEFAULT PRIVILEGES IN SCHEMA myschema REVOKE SELECT ON TABLES FROM PUBLIC;
ALTER DEFAULT PRIVILEGES IN SCHEMA myschema REVOKE INSERT ON TABLES FROM webuser;
```

Remove the public EXECUTE permission that is normally granted on functions, for all functions subsequently created by role `admin`:

```
ALTER DEFAULT PRIVILEGES FOR ROLE admin REVOKE EXECUTE ON FUNCTIONS FROM PUBLIC;
```

Note however that you *cannot* accomplish that effect with a command limited to a single schema. The following command has no effect, unless it is undoing a matching `GRANT`:

```
ALTER DEFAULT PRIVILEGES IN SCHEMA public REVOKE EXECUTE ON FUNCTIONS FROM PUBLIC;
```

That's because per-schema default privileges can only add privileges to the global setting, not remove privileges granted by it.

Compatibility

There is no `ALTER DEFAULT PRIVILEGES` statement in the SQL standard.

See Also

GRANT, REVOKE

Parent topic: SQL Commands

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7.1.7 ALTER DOMAIN

Changes the definition of a domain.

Synopsis

```
ALTER DOMAIN <name> { SET DEFAULT <expression> | DROP DEFAULT }

ALTER DOMAIN <name> { SET | DROP } NOT NULL

ALTER DOMAIN <name> ADD <domain_constraint> [ NOT VALID ]

ALTER DOMAIN <name> DROP CONSTRAINT [ IF EXISTS ] <constraint_name> [RESTRICT | CASCADE]

ALTER DOMAIN <name> RENAME CONSTRAINT <constraint_name> TO <new_constraint_name>

ALTER DOMAIN <name> VALIDATE CONSTRAINT <constraint_name>

ALTER DOMAIN <name> OWNER TO { <new_owner> | CURRENT_USER | SESSION_USER }

ALTER DOMAIN <name> RENAME TO <new_name>

ALTER DOMAIN <name> SET SCHEMA <new_schema>
```

Description

`ALTER DOMAIN` changes the definition of an existing domain. There are several sub-forms:

- **SET/DROP DEFAULT** — These forms set or remove the default value for a domain. Note that defaults only apply to subsequent `INSERT` commands. They do not affect rows already in a table using the domain.
- **SET/DROP NOT NULL** — These forms change whether a domain is marked to allow NULL values or to reject NULL values. You may only `SET NOT NULL` when the columns using the domain contain no null values.
- **ADD domain_constraint [NOT VALID]** — This form adds a new constraint to a domain using the same syntax as CREATE DOMAIN. When a new constraint is added to a domain, all columns using that domain will be checked against the newly-added constraint. These checks can be suppressed by adding the new constraint using the `NOT VALID` option; the constraint can later be made valid using `ALTER DOMAIN ... VALIDATE CONSTRAINT`. Newly inserted or updated rows are always checked against all constraints, even those marked `NOT VALID`. `NOT VALID` is only accepted for `CHECK` constraints.
- **DROP CONSTRAINT [IF EXISTS]** — This form drops constraints on a domain. If `IF EXISTS` is specified and the constraint does not exist, no error is thrown. In this case a notice is issued instead.
- **RENAME CONSTRAINT** — This form changes the name of a constraint on a domain.
- **VALIDATE CONSTRAINT** — This form validates a constraint previously added as `NOT VALID`, that is, it verifies that all values in table columns of the domain satisfy the specified constraint.
- **OWNER** — This form changes the owner of the domain to the specified user.
- **RENAME** — This form changes the name of the domain.
- **SET SCHEMA** — This form changes the schema of the domain. Any constraints associated with the domain are moved into the new schema as well.

You must own the domain to use `ALTER DOMAIN`. To change the schema of a domain, you must also have `CREATE` privilege on the new schema. To alter the owner, you must also be a direct or indirect member of the new owning role, and that role must have `CREATE` privilege on the domain's schema. (These restrictions enforce that altering the owner does not do anything you could not do by dropping and recreating the domain. However, a superuser can alter ownership of any domain anyway.)

Parameters

name The name (optionally schema-qualified) of an existing domain to alter.

domain_constraint New domain constraint for the domain.

constraint_name Name of an existing constraint to drop or rename.

NOT VALID Do not verify existing column data for constraint validity.

CASCADE Automatically drop objects that depend on the constraint, and in turn all objects that depend on those objects.

RESTRICT Refuse to drop the constraint if there are any dependent objects. This is the default behavior.

new_name The new name for the domain.

new_constraint_name The new name for the constraint.

new_owner The user name of the new owner of the domain.

new_schema The new schema for the domain.

Notes

Although `ALTER DOMAIN ADD CONSTRAINT` attempts to verify that existing stored data satisfies the new constraint, this check is not bulletproof, because the command cannot "see" table rows that are newly inserted or updated and not yet committed. If there is a hazard that concurrent operations might insert bad data, the way to proceed is to add the constraint using the `NOT VALID` option, commit that command, wait until all transactions started before that commit have finished, and then issue `ALTER DOMAIN VALIDATE CONSTRAINT` to search for data violating the constraint. This method is reliable because once the constraint is committed, all new transactions are guaranteed to enforce it against new values of the domain type.

Currently, `ALTER DOMAIN ADD CONSTRAINT`, `ALTER DOMAIN VALIDATE CONSTRAINT`, and `ALTER DOMAIN SET NOT NULL` will fail if the named domain or any derived domain is used within a container-type column (a composite, array, or range column) in any table in the database. They should eventually be improved to be able to verify the new constraint for such nested values.

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Examples

To add a `NOT NULL` constraint to a domain:

```
ALTER DOMAIN zipcode SET NOT NULL;
```

To remove a `NOT NULL` constraint from a domain:

```
ALTER DOMAIN zipcode DROP NOT NULL;
```

To add a check constraint to a domain:

```
ALTER DOMAIN zipcode ADD CONSTRAINT zipchk CHECK (char_length(VALUE) = 5);
```

To remove a check constraint from a domain:

```
ALTER DOMAIN zipcode DROP CONSTRAINT zipchk;
```

To rename a check constraint on a domain:

```
ALTER DOMAIN zipcode RENAME CONSTRAINT zipchk TO zip_check;
```

To move the domain into a different schema:

```
ALTER DOMAIN zipcode SET SCHEMA customers;
```

Compatibility

`ALTER DOMAIN` conforms to the SQL standard, except for the `OWNER`, `RENAME`, `SET SCHEMA`, and `VALIDATE CONSTRAINT` variants, which are WarehousePG extensions. The `NOT VALID` clause of the `ADD CONSTRAINT` variant is also a WarehousePG extension.

See Also

CREATE DOMAIN, DROP DOMAIN

Parent topic: SQL Commands

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7.1.8 ALTER EXTENSION

Change the definition of an extension.

Synopsis

```
ALTER EXTENSION <name> UPDATE [ TO <new_version> ]
ALTER EXTENSION <name> SET SCHEMA <new_schema>
ALTER EXTENSION <name> ADD <member_object>
ALTER EXTENSION <name> DROP <member_object>

where <member_object> is:

  ACCESS METHOD <object_name> |
  AGGREGATE <aggregate_name> ( <aggregate_signature> ) |
  CAST (<source_type> AS <target_type>) |
  COLLATION <object_name> |
  CONVERSION <object_name> |
  DOMAIN <object_name> |
  EVENT TRIGGER <object_name> |
  FOREIGN DATA WRAPPER <object_name> |
  FOREIGN TABLE <object_name> |
  FUNCTION <function_name> ( [ [ <argmode> ] [ <argname> ] <argtype> [, ...] ] ) |
  MATERIALIZED VIEW <object_name> |
  OPERATOR <operator_name> (<left_type>, <right_type>) |
  OPERATOR CLASS <object_name> USING <index_method> |
  OPERATOR FAMILY <object_name> USING <index_method> |
  [ PROCEDURAL ] LANGUAGE <object_name> |
  PROCEDURE <procedure_name> [ ( [ [ <argmode> ] [ <argname> ] <argtype> [, ...] ] ) ] |
  ROUTINE <routine_name> [ ( [ [ <argmode> ] [ <argname> ] <argtype> [, ...] ] ) ] |
  SCHEMA <object_name> |
  SEQUENCE <object_name> |
  SERVER <object_name> |
  TABLE <object_name> |
  TEXT SEARCH CONFIGURATION <object_name> |
  TEXT SEARCH DICTIONARY <object_name> |
  TEXT SEARCH PARSER <object_name> |
  TEXT SEARCH TEMPLATE <object_name> |
  TRANSFORM FOR <type_name> LANGUAGE <lang_name> |
  TYPE <object_name> |
  VIEW <object_name>

and <aggregate_signature> is:

* |
[ <argmode> ] [ <argname> ] <argtype> [ , ... ] |
[ [ <argmode> ] [ <argname> ] <argtype> [ , ... ] ] ORDER BY [ <argmode> ] [ <argname> ] <argtype> [ , ... ]
```

Description

`ALTER EXTENSION` changes the definition of an installed extension. There are several subforms:

UPDATE This form updates the extension to a newer version. The extension must supply a suitable update script (or series of scripts) that can modify the currently-installed version into the requested version.

SET SCHEMA This form moves the extension member objects into another schema. The extension must be*relocatable* for this command to succeed.

ADD member_object This form adds an existing object to the extension. This is mainly useful in extension update scripts. The object will subsequently be treated as a member of the extension; notably, it can only be dropped by dropping the extension.

DROP member_object This form removes a member object from the extension. This is mainly useful in extension update scripts. The object is not dropped, only disassociated from the extension.

See Packaging Related Objects into an Extension for more information about these operations.

You must own the extension to use `ALTER EXTENSION`. The `ADD` and `DROP` forms also require ownership of the object that is being added or dropped.

Parameters

name The name of an installed extension.

new_version The new version of the extension. The new_version can be either an identifier or a string literal. If not specified, `ALTER EXTENSION UPDATE` attempts to update to whatever is shown as the default version in the extension's control file.

new_schema The new schema for the extension.

object_name aggregate_name function_name operator_name procedure_name routine_name The name of an object to be added to or removed from the extension. Names of tables, aggregates, domains, foreign tables, functions, operators, operator classes, operator families, procedures, routines, sequences, text search objects, types, and views can be schema-qualified.

source_type The name of the source data type of the cast.

target_type The name of the target data type of the cast.

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argmode The mode of a function or aggregate argument: `IN`, `OUT`, `INOUT`, or `VARIADIC`. If omitted, the default is `IN`. Note that `ALTER EXTENSION` does not actually pay any attention to `OUT` arguments, since only the input arguments are needed to determine the function's identity. So it is sufficient to list the `IN`, `INOUT`, and `VARIADIC` arguments.

argname The name of a function or aggregate argument. Note that `ALTER EXTENSION` does not actually pay any attention to argument names, since only the argument data types are needed to determine the function's identity.

argtype The data type of a function, procedure, or aggregate argument.

left_type right_type The data types of the operator's arguments (optionally schema-qualified). Specify `NONE` for the missing argument of a prefix or postfix operator.

PROCEDURAL This is a noise word.

type_name The name of the data type of the transform.

lang_name The name of the language of the transform.

Examples

To update the hstore extension to version 2.0:

```
ALTER EXTENSION hstore UPDATE TO '2.0';
```

To change the schema of the `hstore` extension to `utils`:

```
ALTER EXTENSION hstore SET SCHEMA utils;
```

To add an existing function to the `hstore` extension:

```
ALTER EXTENSION hstore ADD FUNCTION populate_record(anyelement, hstore);
```

Compatibility

`ALTER EXTENSION` is a WarehousePG extension.

See Also

CREATE EXTENSION, DROP EXTENSION

Parent topic: SQL Commands

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7.1.9 ALTER EXTERNAL TABLE

Changes the definition of an external table.

Synopsis

```
ALTER EXTERNAL TABLE <name> <action> [, ... ]
```

where action is one of:

```
  ADD [COLUMN] <new_column> <type>
  DROP [COLUMN] <column> [RESTRICT|CASCADE]
  ALTER [COLUMN] <column> TYPE <type>
  OWNER TO <new_owner>
```

Description

`ALTER EXTERNAL TABLE` changes the definition of an existing external table. These are the supported `ALTER EXTERNAL TABLE` actions:

- **ADD COLUMN** — Adds a new column to the external table definition.
- **DROP COLUMN** — Drops a column from the external table definition. If you drop readable external table columns, it only changes the table definition in WarehousePG. The `CASCADE` keyword is required if anything outside the table depends on the column, such as a view that references the column.
- **ALTER COLUMN TYPE** — Changes the data type of a table column.
- **OWNER** — Changes the owner of the external table to the specified user.

Use the ALTER TABLE command to perform these actions on an external table:

- Set (change) the table schema.
- Rename the table.
- Rename a table column.
- Set (change) the distribution policy (writable external table only).

You must own the external table to use `ALTER EXTERNAL TABLE` or `ALTER TABLE`. To change the schema of an external table, you must also have `CREATE` privilege on the new schema. To alter the owner, you must also be a direct or indirect member of the new owning role, and that role must have `CREATE` privilege on the external table's schema. A superuser has these privileges automatically.

Changes that you make to an external table definition with either `ALTER EXTERNAL TABLE` or `ALTER TABLE` do not affect the external data.

The `ALTER EXTERNAL TABLE` and `ALTER TABLE` commands cannot modify the type of the external table (read, write, web), the table `FORMAT` information, or the location of the external data. To modify this information, you must drop and recreate the external table definition.

Parameters

name The name (possibly schema-qualified) of an existing external table definition to alter.

column Name of an existing column.

new_column Name of a new column.

type Data type of the new column, or new data type for an existing column.

new_owner The role name of the new owner of the external table.

CASCADE Automatically drop objects that depend on the dropped column, such as a view that references the column.

RESTRICT Refuse to drop the column or constraint if there are any dependent objects. This is the default behavior.

Examples

Add a new column to an external table definition:

```
ALTER EXTERNAL TABLE ext_expenses ADD COLUMN manager text;
```

Change the owner of an external table:

```
ALTER EXTERNAL TABLE ext_data OWNER TO jojo;
```

Change the data type of an external table:

```
ALTER EXTERNAL TABLE ext_leads ALTER COLUMN acct_code TYPE integer;
```

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Compatibility

`ALTER EXTERNAL TABLE` is a WarehousePG extension. There is no `ALTER EXTERNAL TABLE` statement in the SQL standard or regular PostgreSQL.

See Also

CREATE EXTERNAL TABLE, DROP EXTERNAL TABLE, ALTER TABLE

Parent topic: SQL Commands

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7.1.10 ALTER FOREIGN DATA WRAPPER

Changes the definition of a foreign-data wrapper.

Synopsis

```
ALTER FOREIGN DATA WRAPPER <name>
    [ HANDLER <handler_function> | NO HANDLER ]
    [ VALIDATOR <validator_function> | NO VALIDATOR ]
    [ OPTIONS ( [ ADD | SET | DROP ] <option> ['<value>'] [, ... ] ) ]

ALTER FOREIGN DATA WRAPPER <name> OWNER TO { <new_owner> | CURRENT_USER | SESSION_USER }
ALTER FOREIGN DATA WRAPPER <name> RENAME TO <new_name>
```

Description

`ALTER FOREIGN DATA WRAPPER` changes the definition of a foreign-data wrapper. The first form of the command changes the support functions or generic options of the foreign-data wrapper. WarehousePG requires at least one clause. The second and third forms of the command change the owner or name of the foreign-data wrapper.

Only superusers can alter foreign-data wrappers. Additionally, only superusers can own foreign-data wrappers

Parameters

name The name of an existing foreign-data wrapper.

HANDLER handler_function Specifies a new handler function for the foreign-data wrapper.

NO HANDLER Specifies that the foreign-data wrapper should no longer have a handler function.

```
> **Note** You cannot access a foreign table that uses a foreign-data wrapper with no handler.
```

VALIDATOR validator_function Specifies a new validator function for the foreign-data wrapper.

Note that it is possible that pre-existing options of the foreign-data wrapper, or of dependent servers, user mappings, or foreign tables, may become invalid when you change the validator function. WarehousePG does not check for this. You must make sure that these options are correct before using the modified foreign-data wrapper. However, WarehousePG will check any options specified in this `ALTER FOREIGN DATA WRAPPER` command using the new validator.

NO VALIDATOR Specifies that the foreign-data wrapper should no longer have a validator function.

OPTIONS ([ADD | SET | DROP] option ['value'] [, ...]) Change the foreign-data wrapper's options `ADD`, `SET`, and `DROP` specify the action to perform. If no operation is explicitly specified, the default operation is `ADD`. Option names must be unique. WarehousePG validates names and values using the foreign-data wrapper's validator function, if any.

OWNER TO new_owner Specifies the user name of the new owner of the foreign-data wrapper. Only superusers can own foreign-data wrappers.

RENAME TO new_name Specifies the new name of the foreign-data wrapper.

Examples

Change the definition of a foreign-data wrapper named `dbi` by adding a new option named `foo`, and removing the option named `bar`:

```
ALTER FOREIGN DATA WRAPPER dbi OPTIONS (ADD foo '1', DROP 'bar');
```

Change the validator function for a foreign-data wrapper named `dbi` to `bob.myvalidator`:

```
ALTER FOREIGN DATA WRAPPER dbi VALIDATOR bob.myvalidator;
```

Compatibility

`ALTER FOREIGN DATA WRAPPER` conforms to ISO/IEC 9075-9 (SQL/MED), with the exception that the `HANDLER`, `VALIDATOR`, `OWNER TO`, and `RENAME TO` clauses are WarehousePG extensions.

See Also

CREATE FOREIGN DATA WRAPPER, DROP FOREIGN DATA WRAPPER

Parent topic: SQL Commands

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7.1.11 ALTER FOREIGN TABLE

Changes the definition of a foreign table.

Synopsis

```
ALTER FOREIGN TABLE [ IF EXISTS ] [ONLY] <name> [ * ]
    <action> [, ... ]
ALTER FOREIGN TABLE [ IF EXISTS ] [ONLY] <name> [ * ]
    RENAME [ COLUMN ] <column_name> TO <new_column_name>
ALTER FOREIGN TABLE [ IF EXISTS ] <name>
    RENAME TO <new_name>
ALTER FOREIGN TABLE [ IF EXISTS ] <name>
    SET SCHEMA <new_schema>

where <action> is one of:

    ADD [ COLUMN ] <column_name> <data_type> [ COLLATE <collation> ] [ <column_constraint> [ ... ] ]
    DROP [ COLUMN ] [ IF EXISTS ] <column_name> [ RESTRICT | CASCADE ]
    ALTER [ COLUMN ] <column_name> [ SET DATA ] TYPE <data_type> [ COLLATE <collation> ]
    ALTER [ COLUMN ] <column_name> SET DEFAULT <expression>
    ALTER [ COLUMN ] <column_name> DROP DEFAULT
    ALTER [ COLUMN ] <column_name> { SET | DROP } NOT NULL
    ALTER [ COLUMN ] <column_name> SET STATISTICS <integer>
    ALTER [ COLUMN ] <column_name> SET ( <attribute_option> = <value> [, ... ] )
    ALTER [ COLUMN ] <column_name> RESET ( <attribute_option> [, ... ] )
    ALTER [ COLUMN ] <column_name> SET STORAGE { PLAIN | EXTERNAL | EXTENDED | MAIN }
    ALTER [ COLUMN ] <column_name> OPTIONS ( [ ADD | SET | DROP ] <option> ['<value>'] [, ... ])
    ADD <table_constraint> [ NOT VALID ]
    VALIDATE CONSTRAINT <constraint_name>
    DROP CONSTRAINT [ IF EXISTS ]  <constraint_name> [ RESTRICT | CASCADE ]
    DISABLE TRIGGER [ <trigger_name> | ALL | USER ]
    ENABLE TRIGGER [ <trigger_name> | ALL | USER ]
    ENABLE REPLICA TRIGGER <trigger_name>
    ENABLE ALWAYS TRIGGER <trigger_name>
    SET WITHOUT OIDS
    INHERIT <parent_table>
    NO INHERIT <parent_table>
    OWNER TO { <new_owner> | CURRENT_USER | SESSION_USER }
    OPTIONS ( [ ADD | SET | DROP ] <option> ['<value>'] [, ... ] )
```

Description

`ALTER FOREIGN TABLE` changes the definition of an existing foreign table. There are several subforms of the command:

ADD COLUMN This form adds a new column to the foreign table, using the same syntax as CREATE FOREIGN TABLE. Unlike the case when you add a column to a regular table, nothing happens to the underlying storage: this action simply declares that some new column is now accessible through the foreign table.

DROP COLUMN [IF EXISTS] This form drops a column from a foreign table. You must specify `CASCADE` if any objects outside of the table depend on the column; for example, views. If you specify `IF EXISTS` and the column does not exist, no error is thrown. In this case, WarehousePG issues a notice instead.

IF EXISTS If you specify `IF EXISTS` and the foreign table does not exist, no error is thrown. WarehousePG issues a notice instead.

SET DATA TYPE This form changes the type of a column of a foreign table. Again, this has no effect on any underlying storage: this action simply changes the type that WarehousePG believes the column to have.

SET/DROP DEFAULT These forms set or remove the default value for a column. Default values apply only in subsequent `INSERT` or `UPDATE` commands; they do not cause rows already in the table to change.

SET/DROP NOT NULL Mark a column as allowing, or not allowing, null values.

SET STATISTICS This form sets the per-column statistics-gathering target for subsequent `ANALYZE` operations. See the similar form of ALTER TABLE for more details.

SET (attribute_option = value [, ...]) RESET (attribute_option [, ...]) This form sets or resets per-attribute options. See the similar form of ALTER TABLE for more details.

SET STORAGE This form sets the storage mode for a column. See the similar form of ALTER TABLE for more details. Note that the storage mode has no effect unless the table's foreign-data wrapper chooses to pay attention to it.

ADD table_constraint [NOT VALID] This form adds a new constraint to a foreign table, using the same syntax as CREATE FOREIGN TABLE. Currently only `CHECK` constraints are supported. Unlike the case when adding a constraint to a regular table, nothing is done to verify the constraint is correct; rather, this action simply declares that some new condition should be assumed to hold for all rows in the foreign table. (See the discussion in CREATE FOREIGN TABLE.) If the constraint is marked `NOT VALID`, then it isn't assumed to hold, but is only recorded for possible future use.

VALIDATE CONSTRAINT This form marks as valid a constraint that was previously marked as `NOT VALID`. No action is taken to verify the constraint, but future queries will assume that it holds.

DROP CONSTRAINT [IF EXISTS] This form drops the specified constraint on a foreign table. If `IF EXISTS` is specified and the constraint does not exist, no error is thrown. In this case a notice is issued instead.

DISABLE/ENABLE [REPLICA | ALWAYS] TRIGGER These forms configure the firing of trigger(s) belonging to the foreign table. See the similar form of ALTER TABLE for more details.

SET WITHOUT OIDS Backward compatibility syntax for removing the oid system column. As oid system columns cannot be added anymore, this never has an effect.

INHERIT parent_table This form adds the target foreign table as a new child of the specified parent table. See the similar form of ALTER TABLE for more details.

NO INHERIT parent_table This form removes the target foreign table from the list of children of the specified parent table.

OWNER This form changes the owner of the foreign table to the specified user.

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RENAME The `RENAME` forms change the name of a foreign table or the name of an individual column in a foreign table.

SET SCHEMA This form moves the foreign table into another schema.

OPTIONS ([ADD | SET | DROP] option ['value'] [, ...]) Change options for the foreign table. `ADD`, `SET`, and `DROP` specify the action to perform. If no operation is explicitly specified, the default operation is `ADD`. Option names must be unique (although it's OK for a table option and a column option to have the same name). WarehousePG also validates names and values using the server's foreign-data wrapper.

You can combine all of the actions except `RENAME` and `SET SCHEMA` into a list of multiple alterations for WarehousePG to apply in parallel. For example, it is possible to add several columns and/or alter the type of several columns in a single command.

If the command is written as `ALTER FOREIGN TABLE IF EXISTS ...` and the foreign table does not exist, no error is thrown. A notice is issued in this case.

You must own the table to use `ALTER FOREIGN TABLE`. To change the schema of a foreign table, you must also have `CREATE` privilege on the new schema. To alter the owner, you must also be a direct or indirect member of the new owning role, and that role must have `CREATE` privilege on the table's schema. (These restrictions enforce that altering the owner doesn't do anything you couldn't do by dropping and recreating the table. However, a superuser can alter ownership of any table anyway.) To add a column or to alter a column type, you must also have `USAGE` privilege on the data type.

Parameters

name The name (possibly schema-qualified) of an existing foreign table to alter. If `ONLY` is specified before the table name, only that table is altered. If `ONLY` is not specified, the table and all its descendant tables (if any) are altered. Optionally, `*` can be specified after the table name to explicitly indicate that descendant tables are included.

column_name The name of a new or existing column.

new_column_name The new name for an existing column.

new_name The new name for the foreign table.

data_type The data type of the new column, or new data type for an existing column.

table_constraint The new table constraint for the foreign table.

constraint_name The name of an existing constraint to validate or drop.

CASCADE Automatically drop objects that depend on the dropped column or constraint (for example, views referencing the column), and in turn all objects that depend on those objects.

RESTRICT Refuse to drop the column or constraint if there are any dependent objects. This is the default behavior.

trigger_name Name of a single trigger to deactivate or enable.

ALL Deactivate or activate all triggers belonging to the foreign table. (This requires superuser privilege if any of the triggers are internally generated triggers. The core system does not add such triggers to foreign tables, but add-on code could do so.)

USER Deactivate or activate all triggers belonging to the foreign table except for internally generated triggers.

parent_table A parent table to associate or de-associate with this foreign table.

new_owner The user name of the new owner of the foreign table.

new_schema The name of the schema to which the foreign table will be moved.

Notes

The key word `COLUMN` is noise and can be omitted.

Consistency with the foreign server is not checked when a column is added or removed with `ADD COLUMN` or `DROP COLUMN`, a `NOT NULL` or `CHECK` constraint is added, or a column type is changed with `SET DATA TYPE`. It is your responsibility to ensure that the table definition matches the remote side.

Refer to CREATE FOREIGN TABLE for a further description of valid parameters.

Examples

To mark a column as not-null:

```
ALTER FOREIGN TABLE distributors ALTER COLUMN street SET NOT NULL;
```

To change the options of a foreign table:

```
ALTER FOREIGN TABLE myschema.distributors
    OPTIONS (ADD opt1 'value', SET opt2 'value2', DROP opt3 'value3');
```

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Compatibility

The forms `ADD`, `DROP`, and `SET DATA TYPE` conform with the SQL standard. The other forms are WarehousePG extensions of the SQL standard. The ability to specify more than one manipulation in a single `ALTER FOREIGN TABLE` command is also a WarehousePG extension.

You can use `ALTER FOREIGN TABLE ... DROP COLUMN` to drop the only column of a foreign table, leaving a zero-column table. This is an extension of SQL, which disallows zero-column foreign tables.

See Also

ALTER TABLE, CREATE FOREIGN TABLE, DROP FOREIGN TABLE

Parent topic: SQL Commands

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7.1.12 ALTER FUNCTION

Changes the definition of a function.

Synopsis

```
ALTER FUNCTION <name> [ ( [ [<argmode>] [<argname>] <argtype> [, ...] ] ) ]
   <action> [, ... ] [RESTRICT]

ALTER FUNCTION <name> [ ( [ [<argmode>] [<argname>] <argtype> [, ...] ] ) ]
   RENAME TO <new_name>

ALTER FUNCTION <name> [ ( [ [<argmode>] [<argname>] <argtype> [, ...] ] ) ]
   OWNER TO { <new_owner> | CURRENT_USER | SESSION_USER }

ALTER FUNCTION <name> [ ( [ [<argmode>] [<argname>] <argtype> [, ...] ] ) ]
   SET SCHEMA <new_schema>

ALTER FUNCTION <name> [ ( [ [<argmode>] [<argname>] <argtype> [, ...] ] ) ]
   DEPENDS ON EXTENSION <extension_name>

where <action> is one of:

    { CALLED ON NULL INPUT | RETURNS NULL ON NULL INPUT | STRICT }
    { IMMUTABLE | STABLE | VOLATILE }
    [ NOT ] LEAKPROOF
    { [EXTERNAL] SECURITY INVOKER | [EXTERNAL] SECURITY DEFINER }
    PARALLEL { UNSAFE | RESTRICTED | SAFE }
    EXECUTE ON { ANY | COORDINATOR | ALL SEGMENTS | INITPLAN }
    COST <execution_cost>
    ROWS <result_rows>
    SUPPORT <support_function>
    SET <configuration_parameter> { TO | = } { <value> | DEFAULT }
    SET <configuration_parameter> FROM CURRENT
    RESET <configuration_parameter>
    RESET ALL
```

Description

`ALTER FUNCTION` changes the definition of a function.

You must own the function to use `ALTER FUNCTION`. To change a function's schema, you must also have `CREATE` privilege on the new schema. To alter the owner, you must also be a direct or indirect member of the new owning role, and that role must have `CREATE` privilege on the function's schema. (These restrictions enforce that altering the owner does not do anything you could not do by dropping and recreating the function. However, a superuser can alter ownership of any function anyway.)

Parameters

name The name (optionally schema-qualified) of an existing function. If no argument list is specified, the name must be unique in its schema.

argmode The mode of an argument: either `IN`, `OUT`, `INOUT`, or `VARIADIC`. If omitted, the default is `IN`. Note that `ALTER FUNCTION` does not actually pay any attention to `OUT` arguments, since only the input arguments are needed to determine the function's identity. So it is sufficient to list the `IN`, `INOUT`, and `VARIADIC` arguments.

argname The name of an argument. Note that ALTER FUNCTION does not actually pay any attention to argument names, since only the argument data types are needed to determine the function's identity.

argtype The data type(s) of the function's arguments (optionally schema-qualified), if any.

new_name The new name of the function.

new_owner The new owner of the function. Note that if the function is marked `SECURITY DEFINER`, it will subsequently run as the new owner.

new_schema The new schema for the function.

extension_name The name of the extension that the function is to depend on.

CALLED ON NULL INPUT RETURNS NULL ON NULL INPUT STRICT `CALLED ON NULL INPUT` changes the function so that it will be invoked when some or all of its arguments are null. `RETURNS NULL ON NULL INPUT` or `STRICT` changes the function so that it is not invoked if any of its arguments are null; instead, a null result is assumed automatically. SeeCREATE FUNCTION for more information.

IMMUTABLE STABLE VOLATILE Change the volatility of the function to the specified setting. SeeCREATE FUNCTION for details.

[EXTERNAL] SECURITY INVOKER [EXTERNAL] SECURITY DEFINER Change whether the function is a security definer or not. The key word `EXTERNAL` is ignored for SQL conformance. See CREATE FUNCTION for more information about this capability.

PARALLEL Change whether the function is deemed safe for parallelism. See CREATE FUNCTION for details.

LEAKPROOF Change whether the function is considered leakproof or not. See CREATE FUNCTION for more information about this capability.

EXECUTE ON ANY EXECUTE ON COORDINATOR EXECUTE ON ALL SEGMENTS EXECUTE ON INITPLAN The `EXECUTE ON` attributes specify where (coordinator or segment instance) a function runs when it is invoked during the query execution process.

`EXECUTE ON ANY` (the default) indicates that the function can be run on the coordinator, or any segment instance, and it returns the same result regardless of where it is run. WarehousePG determines where the function runs.

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`EXECUTE ON COORDINATOR` indicates that the function must run only on the coordinator instance.

`EXECUTE ON ALL SEGMENTS` indicates that the function must run on all primary segment instances, but not the coordinator, for each invocation. The overall result of the function is the `UNION ALL` of the results from all segment instances.

`EXECUTE ON INITPLAN` indicates that the function contains an SQL command that dispatches queries to the segment instances and requires special processing on the coordinator instance by WarehousePG when possible.

For more information about the `EXECUTE ON` attributes, see CREATE FUNCTION.

COST execution_cost Change the estimated execution cost of the function. See CREATE FUNCTION for more information.

ROWS result_rows Change the estimated number of rows returned by a set-returning function. See CREATE FUNCTION for more information.

SUPPORT support_function Set or change the planner support function to use for this function. You must be superuser to use this option. This option cannot be used to remove the support function altogether, since it must name a new support function. Use `CREATE OR REPLACE FUNCTION` if you require that.

configuration_parameter value Set or change the value of a configuration parameter when the function is called. If value is `DEFAULT` or, equivalently, `RESET` is used, the function-local setting is removed, and the function runs with the value present in its environment. Use `RESET ALL` to clear all function-local settings. `SET FROM CURRENT` saves the value of the parameter that is current when `ALTER FUNCTION` is run as the value to be applied when the function is entered. See SET for more information about allowed parameter names and values.

RESTRICT Ignored for conformance with the SQL standard.

Notes

WarehousePG has limitations on the use of functions defined as `STABLE` or `VOLATILE`. See CREATE FUNCTION for more information.

Examples

To rename the function `sqrt` for type `integer` to `square_root`:

```
ALTER FUNCTION sqrt(integer) RENAME TO square_root;
```

To change the owner of the function `sqrt` for type `integer` to `joe`:

```
ALTER FUNCTION sqrt(integer) OWNER TO joe;
```

To change the schema of the function `sqrt` for type `integer` to `maths`:

```
ALTER FUNCTION sqrt(integer) SET SCHEMA maths;
```

To mark the function `sqrt` for type `integer` as being dependent on the extension `mathlib`:

```
ALTER FUNCTION sqrt(integer) DEPENDS ON EXTENSION mathlib;
```

To adjust the search path that is automatically set for a function:

```
ALTER FUNCTION check_password(text) search_path = admin, pg_temp;
```

To disable automatic setting of `search_path` for a function:

```
ALTER FUNCTION check_password(text) RESET search_path;
```

The function will now execute with whatever search path is used by its caller.

Compatibility

This statement is partially compatible with the `ALTER FUNCTION` statement in the SQL standard. The standard allows more properties of a function to be modified, but does not provide the ability to rename a function, make a function a security definer, attach configuration parameter values to a function, or change the owner, schema, or volatility of a function. The standard also requires the `RESTRICT` key word, which is optional in WarehousePG.

See Also

CREATE FUNCTION, DROP FUNCTION, ALTER PROCEDURE, ALTER ROUTINE

Parent topic: SQL Commands

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7.1.13 ALTER GROUP

Changes a role name or membership.

Synopsis

```
ALTER GROUP <role_specification> ADD USER <user_name> [, ... ]

ALTER GROUP <role_specification> DROP USER <user_name> [, ... ]

where <role_specification> can be:

    <role_name>
  | CURRENT_USER
  | SESSION_USER

ALTER GROUP <group_name> RENAME TO <new_name>
```

Description

`ALTER GROUP` changes the attributes of a user group. This is an obsolete command, though still accepted for backwards compatibility, because users and groups are superseded by the more general concept of roles.

The first two variants add users to a group or remove them from a group. (Any role can play the part of either a "user" or "group" for this purpose. These variants are effectively equivalent to granting or revoking membership in the role named as the "group"; so, the preferred way to do this is to use GRANT or REVOKE.

The third variant changes the name of the group. This is exactly equivalent to renaming the role withALTER ROLE.

Parameters

group_name The name of the group (role) to modify.

user_name Users (roles) that are to be added to or removed from the group. The users (roles) must already exist; `ALTER GROUP` does not create or drop users.

new_name The new name of the group.

Examples

To add users to a group:

```
ALTER GROUP staff ADD USER karl, john;
```

To remove a user from a group:

```
ALTER GROUP workers DROP USER beth;
```

Compatibility

There is no `ALTER GROUP` statement in the SQL standard.

See Also

ALTER ROLE, GRANT, REVOKE

Parent topic: SQL Commands

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7.1.14 ALTER INDEX

Changes the definition of an index.

Synopsis

```
ALTER INDEX [ IF EXISTS ] <name> RENAME TO <new_name>
ALTER INDEX [ IF EXISTS ] <name> SET TABLESPACE <tablespace_name>
ALTER INDEX <name> ATTACH PARTITION <index_name>
ALTER INDEX <name DEPENDS ON EXTENSION <extension_name>
ALTER INDEX [ IF EXISTS ] <name> SET ( <storage_parameter> [= <value>] [, ...] )
ALTER INDEX [ IF EXISTS ] <name> RESET ( <storage_parameter>  [, ...] )
ALTER INDEX [ IF EXISTS ] <name> ALTER [ COLUMN ] <column_number>
    SET STATISTICS <integer>
ALTER INDEX ALL IN TABLESPACE <name> [ OWNED BY <role_name> [, ... ] ]
    SET TABLESPACE <new_tablespace> [ NOWAIT ]
```

Description

`ALTER INDEX` changes the definition of an existing index. There are several subforms described below. Note that the lock level required may differ for each subform. An `ACCESS EXCLUSIVE` lock is held unless explicitly noted. When multiple subcommands are listed, the lock held will be the strictest one required from any subcommand.

RENAME Changes the name of the index. If the index is associated with a table constraint (either `UNIQUE`, `PRIMARY KEY`, or `EXCLUDE`), the constraint is renamed as well. There is no effect on the stored data. Renaming an index acquires a `SHARE UPDATE EXCLUSIVE` lock.

SET TABLESPACE Changes the index's tablespace to the specified tablespace and moves the data file(s) associated with the index to the new tablespace. To change the tablespace of an index, you must own the index and have `CREATE` privilege on the new tablespace. All indexes in the current database in a tablespace can be moved by using the `ALL IN TABLESPACE` form, which will lock all indexes to be moved and then move each one. This form also supports `OWNED BY`, which will only move indexes owned by the roles specified. If the `NOWAIT` option is specified then the command will fail if it is unable to acquire all of the locks required immediately. Note that system catalogs will not be moved by this command, use `ALTER DATABASE` or explicit `ALTER INDEX` invocations instead if desired. See also CREATE TABLESPACE.

ATTACH PARTITION Causes the named index to become attached to the altered index. The named index must be on a partition of the table containing the index being altered, and have an equivalent definition. An attached index cannot be dropped by itself, and will automatically be dropped if its parent index is dropped.

DEPENDS ON EXTENSION This form marks the index as dependent on the extension, such that if the extension is dropped, the index will automatically be dropped as well.

SET (storage_parameter [= value][, ...]) Changes one or more index-method-specific storage parameters for the index. See CREATE INDEX for details on the available parameters. Note that the index contents will not be modified immediately by this command; depending on the parameter you might need to rebuild the index with REINDEX to get the desired effects.

RESET (storage_parameter [, ...]) Resets one or more index-method-specific storage parameters for the index to their defaults. As with `SET`, a `REINDEX` may be needed to update the index entirely.

ALTER [COLUMN] column_number SET STATISTICS integer This form sets the per-column statistics-gathering target for subsequent `ANALYZE` operations, though can be used only on index columns that are defined as an expression. Since expressions lack a unique name, we refer to them using the ordinal number of the index column. The target can be set in the range 0 to 10000; alternatively, set it to `-1` to revert to using the system default statistics target (default_statistics_target).

Parameters

IF EXISTS Do not throw an error if the index does not exist. WarehousePG issues a notice in this case.

column_number The ordinal number refers to the ordinal (left-to-right) position of the index column.

name The name (optionally schema-qualified) of an existing index to alter.

new_name New name for the index.

tablespace_name The tablespace to which the index will be moved.

storage_parameter The name of an index-method-specific storage parameter.

value The new value for an index-method-specific storage parameter. This might be a number or a word depending on the parameter.

Notes

These operations are also possible using ALTER TABLE. `ALTER INDEX` is in fact just an alias for the forms of `ALTER TABLE` that apply to indexes.

There was formerly an `ALTER INDEX OWNER` variant, but this is now ignored (with a warning). An index cannot have an owner different from its table's owner. Changing the table's owner automatically changes the index as well.

Changing any part of a system catalog index is not permitted.

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Examples

To rename an existing index:

```
ALTER INDEX distributors RENAME TO suppliers;
```

To move an index to a different tablespace:

```
ALTER INDEX distributors SET TABLESPACE fasttablespace;
```

To change an index's fill factor (assuming that the index method supports it):

```
ALTER INDEX distributors SET (fillfactor = 75);
REINDEX INDEX distributors;
```

Set the statistics-gathering target for an expression index:

```
CREATE INDEX coord_idx ON measured (x, y, (z + t));
ALTER INDEX coord_idx ALTER COLUMN 3 SET STATISTICS 1000;
```

Compatibility

`ALTER INDEX` is a WarehousePG extension to the SQL standard.

See Also

CREATE INDEX, REINDEX, ALTER TABLE

Parent topic: SQL Commands

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7.1.15 ALTER LANGUAGE

Changes the definition of a procedural language.

Synopsis

```
ALTER [ PROCEDURAL ] LANGUAGE <name> RENAME TO <new_name>
ALTER [ PROCEDURAL ] LANGUAGE <name> OWNER TO { <new_owner> | CURRENT_USER | SESSION_USER }
```

Description

`ALTER LANGUAGE` changes the definition of a procedural language for a specific database. Definition changes supported include renaming the language or assigning a new owner. You must be superuser or the owner of the language to use `ALTER LANGUAGE`.

Parameters

name Name of a language.

new_name The new name of the language.

new_owner The new owner of the language.

Compatibility

There is no `ALTER LANGUAGE` statement in the SQL standard.

See Also

CREATE LANGUAGE, DROP LANGUAGE

Parent topic: SQL Commands

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7.1.16 ALTER MATERIALIZED VIEW

Changes the definition of a materialized view.

Synopsis

```
ALTER MATERIALIZED VIEW [ IF EXISTS ] <name> <action> [, ... ]
ALTER MATERIALIZED VIEW <name>
    DEPENDS ON EXTENSION <extension_name>
ALTER MATERIALIZED VIEW [ IF EXISTS ] <name>
    RENAME [ COLUMN ] <column_name> TO <new_column_name>
ALTER MATERIALIZED VIEW [ IF EXISTS ] <name>
    RENAME TO <new_name>
ALTER MATERIALIZED VIEW [ IF EXISTS ] <name>
    SET SCHEMA <new_schema>
ALTER MATERIALIZED VIEW ALL IN TABLESPACE <name> [ OWNED BY <role_name> [, ... ] ]
    SET TABLESPACE <new_tablespace> [ NOWAIT ]

where <action> is one of:

    ALTER [ COLUMN ] <column_name> SET STATISTICS <integer>
    ALTER [ COLUMN ] <column_name> SET ( <attribute_option> = <value> [, ... ] )
    ALTER [ COLUMN ] <column_name> RESET ( <attribute_option> [, ... ] )
    ALTER [ COLUMN ] <column_name> SET STORAGE { PLAIN | EXTERNAL | EXTENDED | MAIN }
    CLUSTER ON <index_name>
    SET WITHOUT CLUSTER
    SET TABLESPACE <new_tablespace>
    SET ( <storage_paramete>r = <value> [, ... ] )
    RESET ( <storage_parameter> [, ... ] )
    OWNER TO { <new_owner> | CURRENT_USER | SESSION_USER }
```

Description

`ALTER MATERIALIZED VIEW` changes various auxiliary properties of an existing materialized view.

You must own the materialized view to use `ALTER MATERIALIZED VIEW`. To change a materialized view's schema, you must also have `CREATE` privilege on the new schema. To alter the owner, you must also be a direct or indirect member of the new owning role, and that role must have `CREATE` privilege on the materialized view's schema. (These restrictions enforce that altering the owner doesn't do anything you couldn't do by dropping and recreating the materialized view. However, a superuser can alter ownership of any view anyway.)

The `DEPENDS ON EXTENSION` form marks the materialized view as dependent on an extension, such that the materialized view will automatically be dropped if the extension is dropped.

The statement subforms and actions available for `ALTER MATERIALIZED VIEW` are a subset of those available for `ALTER TABLE`, and have the same meaning when used for materialized views. See the descriptions for ALTER TABLE for details.

Parameters

name The name (optionally schema-qualified) of an existing materialized view.

column_name Name of a new or existing column.

extension_name The name of the extension that the materialized view is to depend on.

new_column_name New name for an existing column.

new_owner The user name of the new owner of the materialized view.

new_name The new name for the materialized view.

new_schema The new schema for the materialized view.

Examples

To rename the materialized view `foo` to `bar`:

```
ALTER MATERIALIZED VIEW foo RENAME TO bar;
```

Compatibility

`ALTER MATERIALIZED VIEW` is a WarehousePG extension of the SQL standard.

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See Also

CREATE MATERIALIZED VIEW, DROP MATERIALIZED VIEW, REFRESH MATERIALIZED VIEW

Parent topic: SQL Commands

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7.1.17 ALTER OPERATOR

Changes the definition of an operator.

Synopsis

```
ALTER OPERATOR <name> ( {<left_type> | NONE} , {<right_type> | NONE} )
   OWNER TO { <new_owner> | CURRENT_USER | SESSION_USER }

ALTER OPERATOR <name> ( {<left_type> | NONE} , {<right_type> | NONE} )
    SET SCHEMA <new_schema>

ALTER OPERATOR name ( { <left_type> | NONE } , { <right_type> | NONE } )
    SET ( {  RESTRICT = { <res_proc> | NONE }
           | JOIN = { <join_proc> | NONE }
         } [, ... ] )
```

Description

`ALTER OPERATOR` changes the definition of an operator.

You must own the operator to use `ALTER OPERATOR`. To alter the owner, you must also be a direct or indirect member of the new owning role, and that role must have `CREATE` privilege on the operator's schema. (These restrictions enforce that altering the owner does not do anything you could not do by dropping and recreating the operator. However, a superuser can alter ownership of any operator anyway.)

Parameters

name The name (optionally schema-qualified) of an existing operator.

left_type The data type of the operator's left operand; write `NONE` if the operator has no left operand.

right_type The data type of the operator's right operand; write `NONE` if the operator has no right operand.

new_owner The new owner of the operator.

new_schema The new schema for the operator.

res_proc The restriction selectivity estimator function for this operator; write `NONE` to remove the existing selectivity estimator.

join_proc The join selectivity estimator function for this operator; write `NONE` to remove the existing selectivity estimator.

Examples

Change the owner of a custom operator `a @@ b` for type `text`:

```
ALTER OPERATOR @@ (text, text) OWNER TO joe;
```

Change the restriction and join selectivity estimator functions of a custom operator `a && b` for type `int[]`:

```
ALTER OPERATOR && (_int4, _int4) SET (RESTRICT = _int_contsel, JOIN = _int_contjoinsel);
```

Compatibility

There is no `ALTER OPERATOR` statement in the SQL standard.

See Also

CREATE OPERATOR, DROP OPERATOR

Parent topic: SQL Commands

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7.1.18 ALTER OPERATOR CLASS

Changes the definition of an operator class.

Synopsis

```
ALTER OPERATOR CLASS <name> USING <index_method> RENAME TO <new_name>

ALTER OPERATOR CLASS <name> USING <index_method> OWNER TO { <new_owner> | CURRENT_USER | SESSION_USER }

ALTER OPERATOR CLASS <name> USING <index_method> SET SCHEMA <new_schema>
```

Description

`ALTER OPERATOR CLASS` changes the definition of an operator class.

You must own the operator class to use `ALTER OPERATOR CLASS`. To alter the owner, you must also be a direct or indirect member of the new owning role, and that role must have `CREATE` privilege on the operator class's schema. (These restrictions enforce that altering the owner does not do anything you could not do by dropping and recreating the operator class. However, a superuser can alter ownership of any operator class anyway.)

Parameters

name The name (optionally schema-qualified) of an existing operator class.

index_method The name of the index method this operator class is for.

new_name The new name of the operator class.

new_owner The new owner of the operator class

new_schema The new schema for the operator class.

Compatibility

There is no `ALTER OPERATOR CLASS` statement in the SQL standard.

See Also

CREATE OPERATOR CLASS, DROP OPERATOR CLASS, ALTER OPERATOR FAMILY

Parent topic: SQL Commands

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7.1.19 ALTER OPERATOR FAMILY

Changes the definition of an operator family.

Synopsis

```
ALTER OPERATOR FAMILY <name> USING <index_method> ADD
  {  OPERATOR <strategy_number> <operator_name> ( <op_type>, <op_type> ) [ FOR SEARCH | FOR ORDER BY <sort_family_name> ]
    | FUNCTION <support_number> [ ( <op_type> [ , <op_type> ] ) ] <function_name> ( <argument_type> [, ...] )
  } [, ... ]

ALTER OPERATOR FAMILY <name> USING <index_method> DROP
  {  OPERATOR <strategy_number> ( <op_type> [ , <op_type> ] )
    | FUNCTION <support_number> ( <op_type> [ , <op_type> ] )
  } [, ... ]

ALTER OPERATOR FAMILY <name> USING <index_method> RENAME TO <new_name>

ALTER OPERATOR FAMILY <name> USING <index_method> OWNER TO { <new_owner> | CURRENT_USER | SESSION_USER }

ALTER OPERATOR FAMILY <name> USING <index_method> SET SCHEMA <new_schema>
```

Description

`ALTER OPERATOR FAMILY` changes the definition of an operator family. You can add operators and support functions to the family, remove them from the family, or change the family's name or owner.

When operators and support functions are added to a family with `ALTER OPERATOR FAMILY`, they are not part of any specific operator class within the family, but are just "loose" within the family. This indicates that these operators and functions are compatible with the family's semantics, but are not required for correct functioning of any specific index. (Operators and functions that are so required should be declared as part of an operator class, instead; see CREATE OPERATOR CLASS.) You can drop loose members of a family from the family at any time, but members of an operator class cannot be dropped without dropping the whole class and any indexes that depend on it. Typically, single-data-type operators and functions are part of operator classes because they are needed to support an index on that specific data type, while cross-data-type operators and functions are made loose members of the family.

You must be a superuser to use `ALTER OPERATOR FAMILY`. (This restriction is made because an erroneous operator family definition could confuse or even crash the server.)

`ALTER OPERATOR FAMILY` does not presently check whether the operator family definition includes all the operators and functions required by the index method, nor whether the operators and functions form a self-consistent set. It is the user's responsibility to define a valid operator family.

Parameters

name The name (optionally schema-qualified) of an existing operator family.

index_method The name of the index method this operator family is for.

strategy_number The index method's strategy number for an operator associated with the operator family.

operator_name The name (optionally schema-qualified) of an operator associated with the operator family.

op_type In an `OPERATOR` clause, the operand data type(s) of the operator, or `NONE` to signify a left-unary or right-unary operator. Unlike the comparable syntax in `CREATE OPERATOR CLASS`, the operand data types must always be specified. In an `ADD FUNCTION` clause, the operand data type(s) the function is intended to support, if different from the input data type(s) of the function. For B-tree comparison functions and hash functions it is not necessary to specify op_type since the function's input data type(s) are always the correct ones to use. For B-tree sort support functions and all functions in GiST, SP-GiST, and GIN operator classes, it is necessary to specify the operand data type(s) the function is to be used with. In a `DROP FUNCTION` clause, the operand data type(s) the function is intended to support must be specified.

sort_family_name The name (optionally schema-qualified) of an existing `btree` operator family that describes the sort ordering associated with an ordering operator.

If neither `FOR SEARCH` nor `FOR ORDER BY` is specified, `FOR SEARCH` is the default.

support_number The index method's support function number for a function associated with the operator family.

function_name The name (optionally schema-qualified) of a function that is an index method support function for the operator family. If no argument list is specified, the name must be unique in its schema.

argument_type The parameter data type(s) of the function.

new_name The new name of the operator family.

new_owner The new owner of the operator family.

new_schema The new schema for the operator family.

The `OPERATOR` and `FUNCTION` clauses can appear in any order.

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Notes

Notice that the `DROP` syntax only specifies the "slot" in the operator family, by strategy or support number and input data type(s). The name of the operator or function occupying the slot is not mentioned. Also, for `DROP FUNCTION` the type(s) to specify are the input data type(s) the function is intended to support; for `GiST`, `SP_GiST`, and `GIN` indexes this might have nothing to do with the actual input argument types of the function.

Because the index machinery does not check access permissions on functions before using them, including a function or operator in an operator family is tantamount to granting public execute permission on it. This is usually not an issue for the sorts of functions that are useful in an operator family.

The operators should not be defined by SQL functions. A SQL function is likely to be inlined into the calling query, which will prevent the optimizer from recognizing that the query matches an index.

Before WarehousePG 6.0, the `OPERATOR` clause could include a `RECHECK` option. This option is no longer supported. WarehousePG now determines whether an index operator is "lossy" on-the-fly at run time. This allows more efficient handling of cases where an operator might or might not be lossy.

Examples

The following example command adds cross-data-type operators and support functions to an operator family that already contains B-tree operator classes for data types `int4` and `int2`.:

```
ALTER OPERATOR FAMILY integer_ops USING btree ADD

  -- int4 vs int2
  OPERATOR 1 < (int4, int2) ,
  OPERATOR 2 <= (int4, int2) ,
  OPERATOR 3 = (int4, int2) ,
  OPERATOR 4 >= (int4, int2) ,
  OPERATOR 5 > (int4, int2) ,
  FUNCTION 1 btint42cmp(int4, int2) ,

  -- int2 vs int4
  OPERATOR 1 < (int2, int4) ,
  OPERATOR 2 <= (int2, int4) ,
  OPERATOR 3 = (int2, int4) ,
  OPERATOR 4 >= (int2, int4) ,
  OPERATOR 5 > (int2, int4) ,
  FUNCTION 1 btint24cmp(int2, int4) ;
```

To remove these entries:

```
ALTER OPERATOR FAMILY integer_ops USING btree DROP

  -- int4 vs int2
  OPERATOR 1 (int4, int2) ,
  OPERATOR 2 (int4, int2) ,
  OPERATOR 3 (int4, int2) ,
  OPERATOR 4 (int4, int2) ,
  OPERATOR 5 (int4, int2) ,
  FUNCTION 1 (int4, int2) ,

  -- int2 vs int4
  OPERATOR 1 (int2, int4) ,
  OPERATOR 2 (int2, int4) ,
  OPERATOR 3 (int2, int4) ,
  OPERATOR 4 (int2, int4) ,
  OPERATOR 5 (int2, int4) ,
  FUNCTION 1 (int2, int4) ;
```

Compatibility

There is no `ALTER OPERATOR FAMILY` statement in the SQL standard.

See Also

CREATE OPERATOR FAMILY, DROP OPERATOR FAMILY, ALTER OPERATOR CLASS, CREATE OPERATOR CLASS, DROP OPERATOR CLASS

Parent topic: SQL Commands

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7.1.20 ALTER POLICY

Changes the definition of a row-level security policy.

Synopsis

```
ALTER POLICY <name> ON <table_name> RENAME TO <new_name>

ALTER POLICY <name ON table_name>
    [ TO { <role_name> | PUBLIC | CURRENT_USER | SESSION_USER } [, ...] ]
    [ USING ( <using_expression> ) ]
    [ WITH CHECK ( <check_expression> ) ]
```

Description

`ALTER POLICY` changes the definition of an existing row-level security policy. Note that `ALTER POLICY` only allows the set of roles to which the policy applies and the `USING` and `WITH CHECK` expressions to be modified. To change other properties of a policy, such as the command to which it applies or whether it is permissive or restrictive, the policy must be dropped and recreated.

To use `ALTER POLICY`, you must own the table to which the policy applies.

In the second form of `ALTER POLICY`, the role list, using_expression, and check_expression are replaced independently if specified. When one of those clauses is omitted, the corresponding part of the policy is unchanged.

Parameters

name The name of an existing policy to alter.

table_name The name (optionally schema-qualified) of the table that the policy is on.

new_name The new name for the policy.

role_name The role(s) to which the policy applies. Multiple roles can be specified at one time. To apply the policy to all roles, use `PUBLIC`.

using_expression The `USING` expression for the policy. See CREATE POLICY for details.

check_expression The `WITH CHECK` expression for the policy. See CREATE POLICY for details.

Compatibility

`ALTER POLICY` is a WarehousePG extension to the SQL standard.

See Also

CREATE POLICY, DROP POLICY

Parent topic: SQL Commands

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7.1.21 ALTER PROCEDURE

Changes the definition of a procedure.

Synopsis

```
ALTER PROCEDURE <name> [ ( [ [<argmode>] [<argname>] <argtype> [, ...] ] ) ]
   <action> [, ... ] [RESTRICT]

ALTER PROCEDURE <name> [ ( [ [<argmode>] [<argname>] <argtype> [, ...] ] ) ]
   RENAME TO <new_name>

ALTER PROCEDURE <name> [ ( [ [<argmode>] [<argname>] <argtype> [, ...] ] ) ]
   OWNER TO { <new_owner> | CURRENT_USER | SESSION_USER }

ALTER PROCEDURE <name> [ ( [ [<argmode>] [<argname>] <argtype> [, ...] ] ) ]
   SET SCHEMA <new_schema>

ALTER PROCEDURE <name> [ ( [ [<argmode>] [<argname>] <argtype> [, ...] ] ) ]
   DEPENDS ON EXTENSION <extension_name>

where <action> is one of:

    { [EXTERNAL] SECURITY INVOKER | [EXTERNAL] SECURITY DEFINER }
    SET <configuration_parameter> { TO | = } { <value> | DEFAULT }
    SET <configuration_parameter> FROM CURRENT
    RESET <configuration_parameter>
    RESET ALL
```

Description

`ALTER PROCEDURE` changes the definition of a procedure.

You must own the procedure to use `ALTER PROCEDURE`. To change a procedure's schema, you must also have `CREATE` privilege on the new schema. To alter the owner, you must also be a direct or indirect member of the new owning role, and that role must have `CREATE` privilege on the procedure's schema. (These restrictions enforce that altering the owner doesn't do anything you couldn't do by dropping and recreating the procedure. However, a superuser can alter ownership of any procedure anyway.)

Parameters

name The name (optionally schema-qualified) of an existing procedure. If no argument list is specified, the name must be unique in its schema.

argmode The mode of an argument: `IN` or `VARIADIC`. If omitted, the default is `IN`.

argname The name of an argument. Note that `ALTER PROCEDURE` does not actually pay any attention to argument names, since only the argument data types are needed to determine the function's identity.

argtype The data type(s) of the procedure's arguments (optionally schema-qualified), if any.

new_name The new name of the procedure.

new_owner The new owner of the procedure. Note that if the procedure is marked `SECURITY DEFINER`, it will subsequently run as the new owner.

new_schema The new schema for the procedure.

extension_name The name of the extension that the procedure is to depend on.

[EXTERNAL] SECURITY INVOKER [EXTERNAL] SECURITY DEFINER Change whether the procedure is a security definer or not. The key word `EXTERNAL` is ignored for SQL conformance. See CREATE PROCEDURE for more information about this capability.

configuration_parameter value Set or change the value of a configuration parameter when the procedure is called. If value is `DEFAULT` or, equivalently, `RESET` is used, the procedure-local setting is removed, and the procedure runs with the value present in its environment. Use `RESET ALL` to clear all procedure-local settings. `SET FROM CURRENT` saves the value of the parameter that is current when `ALTER PROCEDURE` is run as the value to be applied when the procedure is entered. See SET for more information about allowed parameter names and values.

RESTRICT Ignored for conformance with the SQL standard.

Notes

WarehousePG has limitations on the use of functions defined as `STABLE` or `VOLATILE`. See CREATE FUNCTION for more information.

Examples

To rename the procedure `insert_data` with two arguments of type `integer` to `insert_record`:

```
ALTER PROCEDURE insert_data(integer, integer) RENAME TO insert_record;
```

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To change the owner of the procedure `insert_data` with two arguments of type `integer` to `joe`:

```
ALTER PROCEDURE insert_data(integer, integer) OWNER TO joe;
```

To change the schema of the procedure `insert_data` with two arguments of type `integer` to `accounting`:

```
ALTER PROCEDURE insert_data(integer, integer) SET SCHEMA accounting;
```

To mark the procedure `insert_data(integer, integer)` as being dependent on the extension `myext`:

```
ALTER PROCEDURE insert_data(integer, integer) DEPENDS ON EXTENSION myext;
```

To adjust the search path that is automatically set for a procedure:

```
ALTER PROCEDURE check_password(text) SET search_path = admin, pg_temp;
```

To disable automatic setting of `search_path` for a procedure:

```
ALTER PROCEDURE check_password(text) RESET search_path;
```

The procedure will now execute with whatever search path is used by its caller.

Compatibility

This statement is partially compatible with the `ALTER PROCEDURE` statement in the SQL standard. The standard allows more properties of a procedure to be modified, but does not provide the ability to rename a procedure, make a procedure a security definer, attach configuration parameter values to a procedure, or change the owner, schema, or volatility of a procedure. The standard also requires the `RESTRICT` key word, which is optional in WarehousePG.

See Also

CREATE PROCEDURE, DROP PROCEDURE

Parent topic: SQL Commands

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7.1.22 ALTER PROTOCOL

Changes the definition of a protocol.

Synopsis

```
ALTER PROTOCOL <name> RENAME TO <newname>

ALTER PROTOCOL <name> OWNER TO <newowner>
```

Description

`ALTER PROTOCOL` changes the definition of a protocol. Only the protocol name or owner can be altered.

You must own the protocol to use `ALTER PROTOCOL`. To alter the owner, you must also be a direct or indirect member of the new owning role, and that role must have `CREATE` privilege on schema of the protocol.

These restrictions are in place to ensure that altering the owner only makes changes that could by made by dropping and recreating the protocol. Note that a superuser can alter ownership of any protocol.

Parameters

name The name (optionally schema-qualified) of an existing protocol.

newname The new name of the protocol.

newowner The new owner of the protocol.

Examples

To rename the protocol `GPDBauth` to `GPDB_authentication`:

```
ALTER PROTOCOL GPDBauth RENAME TO GPDB_authentication;
```

To change the owner of the `GPDB_authentication` protocol to `joe`:

```
ALTER PROTOCOL GPDB_authentication OWNER TO joe;
```

Compatibility

There is no `ALTER PROTOCOL` statement in the SQL standard.

See Also

CREATE EXTERNAL TABLE, CREATE PROTOCOL, DROP PROTOCOL

Parent topic: SQL Commands

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7.1.23 ALTER RESOURCE GROUP

Changes the limits of a resource group.

Synopsis

```
ALTER RESOURCE GROUP <name> SET <group_attribute> <value>
```

where group_attribute is one of:

```
[ CONCURRENCY=<integer> ]
CPU_MAX_PERCENT=<integer> | CPUSET=<coordinator_cores>;<segment_cores>
[ CPU_WEIGHT=<integer> ]
[ MEMORY_QUOTA=<integer> ]
[ MIN_COST=<integer> ]
[ IO_LIMIT=' <tablespace_io_limit_spec> [; ...] ' ]
```

Where `<tablespace_io_limit_spec>` is:

```
<tablespace_name> | <oid> : <io_limit_option_spec> [, ...]
```

Where `<io_limit_option_spec>` is:

```
wbps=<io_limit_option_value>
| rbps=<io_limit_option_value>
| wiops=<io_limit_option_value>
| riops=<io_limit_option_value>
```

Where `<io_limit_option_vlaue>` is:

```
<integer> | max
```

Description

`ALTER RESOURCE GROUP` changes the limits of a resource group. Only a superuser can alter a resource group.

You can set or reset the concurrency limit of a resource group that you create for roles to control the maximum number of active concurrent statements in that group. You can also reset the memory or CPU resources of a resource group to control the amount of memory or CPU resources that all queries submitted through the group can consume on each segment host.

When you alter the CPU resource management mode or limit of a resource group, the new mode or limit is immediately applied.

When you alter a memory quota of a resource group that you create for roles, the new resource limit is immediately applied if current resource usage is less than or equal to the new value and there are no running transactions in the resource group. If the current resource usage exceeds the new memory quota value, or if there are running transactions in other resource groups that hold some of the resource, then WarehousePG defers assigning the new limit until resource usage falls within the range of the new value.

When you increase the memory quota of a resource group that you create for external components, the new resource limit is phased in as system memory resources become available. If you decrease the memory quota of a resource group that you create for external components, the behavior is component-specific.

You can alter one limit type in a single `ALTER RESOURCE GROUP` call.

Parameters

name The name of the resource group to alter.

CONCURRENCY integer The maximum number of concurrent transactions, including active and idle transactions, that are permitted for this resource group. The `CONCURRENCY` value must be an integer in the range [0 .. `max_connections`]. The default `CONCURRENCY` value for resource groups defined for roles is 20.

You must set `CONCURRENCY` to `0` for resource groups that you create for external components.

> **Note** You cannot set the `CONCURRENCY` value for the `admin_group` to `0`.

CPU_MAX_PERCENT integer The percentage of the maximum available CPU resources that the resource group can use. The value range is `1-100`.

CPU_WEIGHT integer The scheduling priority of the current group. The value range is `1-500`, the default is `100.

CPUSET <coordinator_cores>;<segment_cores>

`CPUSET` identifies the CPU cores to reserve for this resource group on the coordinator host and on segment hosts. The CPU cores that you specify must be available in the system and cannot overlap with any CPU cores that you specify for other resource groups.

> **Note** You must specify either `CPU_MAX_PERCENT` or `CPUSET` when you create a resource group, but not both.

Specify cores as a comma-separated list of single core numbers or core number intervals. Define the coordinator host cores first, followed by segment host cores, and separate the two with a semicolon. You must enclose the full core configuration in single quotes. For example, '1;1,3-4' configures core 1 for the coordinator host, and cores 1, 3, and 4 for the segment hosts.

> **Note** You can configure `CPUSET` for a resource group only after you have enabled resource group-based resource management for your WarehousePG cluster.

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IO_LIMIT='<tablespace_io_limit_spec> [; ...]' Optional. The maximum read/write sequential disk I/O throughput, and the maximum read/write I/O operations per second for the queries assigned to a specific resource group.

Where `<tablespace_io_limit_spec>` is:

```
<tablespace_name> | <oid> : <io_limit_option_spec> [, ...]
```

Where `<io_limit_option_spec>` is:

```
wbps=<io_limit_option_value>
| rbps=<io_limit_option_value>
| wiops=<io_limit_option_value>
| riops=<io_limit_option_value>
```

Where `<io_limit_option_vlaue>` is:

```
<integer> | max
```

When you use this parameter, you may speficy:

- The tablespace name or the tablespace object ID (OID) you set the limits for. Use `*` to set limits for all tablespaces.
- The values for `rbps` and `wbps` to limit the maximum read and write sequential disk I/O throughput in the resource group, in MB/S. The default value is `max`, which means there is no limit.
- The values for `riops` and `wiops` to limit the maximum read and write I/O operations per second in the resource group. The default value is `max`, which means there is no limit.

If the parameter `IO_LIMIT` is not set, the default value for `rbps`, `wpbs`, `riops`, and `wiops` s is set to `max`, which means that there are no disk I/O limits. In this scenario, the `gp_toolkit.gp_resgroup_config` system view displays its value as `-1`.

> **Note** The parameter `IO_LIMIT` is only available when you use Linux Control Groups v2. See Configuring and Using Resource Groups for more information.

MEMORY_QUOTA integer The maximum available memory, in MB, to reserve for this resource group. This value determines the total amount of memory that all worker processes within a resource group can consume on a segment host during query execution.

The minimum memory quantity you can specify for a resource group is `0`. The default value is `-1`.

When you specify a `MEMORY_QUOTA` of `-1`, `MEMORY QUOTA` takes the value of the `statement_mem` server configuration parameter.

> **Note** If the server configuration parameter `gp_resgroup_memory_query_fixed_mem` is set, its value overrides at the session level the value of `MEMORY_QUOTA`.

MIN_COST integer The limit on the cost of the query plan generated by a query in this resource group. When the query plan cost of the query is less than this value, the query will be unassigned from the resource group to which it belongs.

This means that low-cost queries will execute more quickly, as they are not subject to resource constraints.

The value range is `0-500`. The default value is `0`, which means that the cost is not used to bypass the query.

Notes

Use CREATE ROLE or ALTER ROLE to assign a specific resource group to a role (user).

You cannot submit an `ALTER RESOURCE GROUP` command in an explicit transaction or sub-transaction.

Examples

Change the active transaction limit for a resource group:

```
ALTER RESOURCE GROUP rgroup1 SET CONCURRENCY 13;
```

Update the CPU limit for a resource group:

```
ALTER RESOURCE GROUP rgroup2 SET CPU_MAX_PERCENT 45;
```

Update the memory quota for a resource group:

```
ALTER RESOURCE GROUP rgroup3 SET MEMORY_QUOTA 300;
```

Reserve CPU core 1 for a resource group on the coordinator host and all segment hosts:

```
ALTER RESOURCE GROUP rgroup5 SET CPUSET '1;1';
```

Set disk I/O limits for tablespaces `tablespace1` and a tablespace with oid 1663:

```
ALTER RESOURCE GROUP admin_group SET IO_LIMIT 'tablespace1:wbps=2000,wiops=2000;1663:rbps=2024,riops=2024';
```

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Compatibility

The `ALTER RESOURCE GROUP` statement is a WarehousePG extension. This command does not exist in standard PostgreSQL.

See Also

CREATE RESOURCE GROUP, DROP RESOURCE GROUP, CREATE ROLE, ALTER ROLE

Parent topic: SQL Commands

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7.1.24 ALTER RESOURCE QUEUE

Changes the limits of a resource queue.

Synopsis

```
ALTER RESOURCE QUEUE <name> WITH ( <queue_attribute>=<value> [, ... ] )
```

where queue_attribute is:

```
   ACTIVE_STATEMENTS=<integer>
   MEMORY_LIMIT='<memory_units>'
   MAX_COST=<float>
   COST_OVERCOMMIT={TRUE|FALSE}
   MIN_COST=<float>
   PRIORITY={MIN|LOW|MEDIUM|HIGH|MAX}
```

```
ALTER RESOURCE QUEUE <name> WITHOUT ( <queue_attribute> [, ... ] )
```

where queue_attribute is:

```
   ACTIVE_STATEMENTS
   MEMORY_LIMIT
   MAX_COST
   COST_OVERCOMMIT
   MIN_COST
```

> **Note** A resource queue must have either an `ACTIVE_STATEMENTS` or a `MAX_COST` value. Do not remove both these `queue_attributes` from a resource queue.

Description

`ALTER RESOURCE QUEUE` changes the limits of a resource queue. Only a superuser can alter a resource queue. A resource queue must have either an `ACTIVE_STATEMENTS` or a `MAX_COST` value (or it can have both). You can also set or reset priority for a resource queue to control the relative share of available CPU resources used by queries associated with the queue, or memory limit of a resource queue to control the amount of memory that all queries submitted through the queue can consume on a segment host.

`ALTER RESOURCE QUEUE WITHOUT` removes the specified limits on a resource that were previously set. A resource queue must have either an `ACTIVE_STATEMENTS` or a `MAX_COST` value. Do not remove both these `queue_attributes` from a resource queue.

Parameters

name The name of the resource queue whose limits are to be altered.

ACTIVE_STATEMENTS integer The number of active statements submitted from users in this resource queue allowed on the system at any one time. The value for `ACTIVE_STATEMENTS` should be an integer greater than 0. To reset `ACTIVE_STATEMENTS` to have no limit, enter a value of `-1`.

MEMORY_LIMIT 'memory_units' Sets the total memory quota for all statements submitted from users in this resource queue. Memory units can be specified in kB, MB or GB. The minimum memory quota for a resource queue is 10MB. There is no maximum; however the upper boundary at query execution time is limited by the physical memory of a segment host. The default value is no limit (`-1`).

MAX_COST float The total query optimizer cost of statements submitted from users in this resource queue allowed on the system at any one time. The value for `MAX_COST` is specified as a floating point number (for example 100.0) or can also be specified as an exponent (for example 1e+2). To reset `MAX_COST` to have no limit, enter a value of `-1.0`.

COST_OVERCOMMIT boolean If a resource queue is limited based on query cost, then the administrator can allow cost overcommit (`COST_OVERCOMMIT=TRUE`, the default). This means that a query that exceeds the allowed cost threshold will be allowed to run but only when the system is idle. If `COST_OVERCOMMIT=FALSE` is specified, queries that exceed the cost limit will always be rejected and never allowed to run.

MIN_COST float Queries with a cost under this limit will not be queued and run immediately. Cost is measured in units of disk page fetches; 1.0 equals one sequential disk page read. The value for `MIN_COST` is specified as a floating point number (for example 100.0) or can also be specified as an exponent (for example 1e+2). To reset `MIN_COST` to have no limit, enter a value of `-1.0`.

PRIORITY={MIN|LOW|MEDIUM|HIGH|MAX} Sets the priority of queries associated with a resource queue. Queries or statements in queues with higher priority levels will receive a larger share of available CPU resources in case of contention. Queries in low-priority queues may be delayed while higher priority queries are run.

Notes

GPORCA and the Postgres-based planner utilize different query costing models and may compute different costs for the same query. The WarehousePG resource queue resource management scheme neither differentiates nor aligns costs between GPORCA and the Postgres-based planner; it uses the literal cost value returned from the optimizer to throttle queries.

When resource queue-based resource management is active, use the `MEMORY_LIMIT` and `ACTIVE_STATEMENTS` limits for resource queues rather than configuring cost-based limits. Even when using GPORCA, WarehousePG may fall back to using the Postgres-based planner for certain queries, so using cost-based limits can lead to unexpected results.

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Examples

Change the active query limit for a resource queue:

```
ALTER RESOURCE QUEUE myqueue WITH (ACTIVE_STATEMENTS=20);
```

Change the memory limit for a resource queue:

```
ALTER RESOURCE QUEUE myqueue WITH (MEMORY_LIMIT='2GB');
```

Reset the maximum and minimum query cost limit for a resource queue to no limit:

```
ALTER RESOURCE QUEUE myqueue WITH (MAX_COST=-1.0,
  MIN_COST= -1.0);
```

Reset the query cost limit for a resource queue to 310 (or 30000000000.0) and do not allow overcommit:

```
ALTER RESOURCE QUEUE myqueue WITH (MAX_COST=3e+10,
  COST_OVERCOMMIT=FALSE);
```

Reset the priority of queries associated with a resource queue to the minimum level:

```
ALTER RESOURCE QUEUE myqueue WITH (PRIORITY=MIN);
```

Remove the `MAX_COST` and `MEMORY_LIMIT` limits from a resource queue:

```
ALTER RESOURCE QUEUE myqueue WITHOUT (MAX_COST, MEMORY_LIMIT);
```

Compatibility

The `ALTER RESOURCE QUEUE` statement is a WarehousePG extension. This command does not exist in standard PostgreSQL.

See Also

CREATE RESOURCE QUEUE, DROP RESOURCE QUEUE, CREATE ROLE, ALTER ROLE

Parent topic: SQL Commands

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7.1.25 ALTER ROLE

Changes a database role (user or group).

Synopsis

```
ALTER ROLE <role_specification> [ WITH ] <option> [ ... ]

where <option> can be:

    SUPERUSER | NOSUPERUSER
  | CREATEDB | NOCREATEDB
  | CREATEROLE | NOCREATEROLE
  | CREATEEXTTABLE | NOCREATEEXTTABLE  [ ( attribute='value' [, ...] )
     where attributes and values are:
       type='readable'|'writable'
       protocol='gpfdist'|'http'
  | INHERIT | NOINHERIT
  | LOGIN | NOLOGIN
  | REPLICATION | NOREPLICATION
  | BYPASSRLS | NOBYPASSRLS
  | CONNECTION LIMIT <connlimit>
  | [ ENCRYPTED ] PASSWORD '<password>' | PASSWORD NULL
  | VALID UNTIL '<timestamp>'
  | [ DENY <deny_point> ]
  | [ DENY BETWEEN <deny_point> AND <deny_point>]
  | [ DROP DENY FOR <deny_point> ]

ALTER ROLE <name> RENAME TO <new_name>

ALTER ROLE { <role_specification> | ALL } [ IN DATABASE <database_name> ] SET <configuration_parameter> { TO | = } { <value> | DEFAULT }
ALTER ROLE { <role_specification> | ALL } [ IN DATABASE <database_name> ] SET <configuration_parameter> FROM CURRENT
ALTER ROLE { <role_specification> | ALL } [ IN DATABASE <database_name> ] RESET <configuration_parameter>
ALTER ROLE { <role_specification> | ALL } [ IN DATABASE <database_name> ] RESET ALL

ALTER ROLE <role_specification> RESOURCE QUEUE {<queue_name> | NONE}
ALTER ROLE <role_specification> RESOURCE GROUP {<group_name> | NONE}

where <role_specification> can be:

    <role_name>
  | CURRENT_USER
  | SESSION_USER
```

Description

`ALTER ROLE` changes the attributes of a WarehousePG role. There are several variants of this command.

WITH option Changes many of the role attributes that can be specified in CREATE ROLE. (All of the possible attributes are covered, execept that there are no options for adding or removing memberships; use GRANT and REVOKE for that.) Attributes not mentioned in the command retain their previous settings. Database superusers can change any of these settings for any role. Roles having `CREATEROLE` privilege can change any of these settings except `SUPERUSER`, `REPLICATION`, and `BYPASSRLS`, but only for non-superuser and non-replication roles. Ordinary roles can only change their own password.

RENAME Changes the name of the role. Database superusers can rename any role. Roles having `CREATEROLE` privilege can rename non-superuser roles. The current session user cannot be renamed (connect as a different user to rename a role). Because MD5-encrypted passwords use the role name as cryptographic salt, renaming a role clears its password if the password is MD5-encrypted.

SET | RESET Changes a role's session default for a specified configuration parameter, either for all databases or, when the `IN DATABASE` clause is specified, only for sessions in the named database. If `ALL` is specified instead of a role name, this changes the setting for all roles. Using `ALL` with `IN DATABASE` is effectively the same as using the command `ALTER DATABASE ... SET ...`.

```
Whenever the role subsequently starts a new session, the specified value becomes the session default, overriding whatever setting is present in the server configuration file \(`postgresql.conf`\) or has been received from the `postgres` command line. This only happens at login time; running [SET ROLE](SET_ROLE.html) or [SET SESSION AUTHORIZATION](SET_SESSION_AUTHORIZATION.html) does not cause new configuration values to be set. Settings set for all databases are overridden by database-specific settings attached to a role. Settings for specific databases or specific roles override settings for all roles.

Superusers can change anyone's session defaults. Roles having `CREATEROLE` privilege can change defaults for non-superuser roles. Ordinary roles can only set defaults for themselves. Certain configuration variables cannot be set this way, or can only be set if a superuser issues the command. Only superusers can change a setting for all roles in all databases.
```

RESOURCE QUEUE Assigns the role to a resource queue. The role would then be subject to the limits assigned to the resource queue when issuing queries. Specify `NONE` to assign the role to the default resource queue. A role can belong to only one resource queue. For a role without `LOGIN` privilege, resource queues have no effect. See CREATE RESOURCE QUEUE for more information.

RESOURCE GROUP Assigns a resource group to the role. The role would then be subject to the concurrent transaction, memory, and CPU limits configured for the resource group. You can assign a single resource group to one or more roles. You cannot assign a resource group that you create for an external component to a role. See CREATE RESOURCE GROUP for additional information.

Parameters

name The name of the role whose attributes are to be altered.

CURRENT_USER Alter the current user instead of an explicitly identified role.

SESSION_USER Alter the current session user instead of an explicitly identified role.

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SUPERUSER NOSUPERUSER CREATEDB NOCREATEDB CREATEROLE NOCREATEROLE INHERIT NOINHERIT LOGIN NOLOGIN REPLICATION NOREPLICATION BYPASSRLS NOBYPASSRLS CONNECTION LIMIT connlimit [ENCRYPTED] PASSWORD 'password' PASSWORD NULL VALID UNTIL 'timestamp' These clauses alter attributes originally set by `CREATE ROLE`. For more information, see the CREATE ROLE reference page.

new_name The new name of the role.

database_name The name of the database in which to set the configuration parameter.

configuration_parameter value Set this role's session default for the specified configuration parameter to the given value. If value is `DEFAULT` or, equivalently, `RESET` is used, the role-specific parameter setting is removed, so the role will inherit the system-wide default setting in new sessions. Use `RESET ALL` to clear all role-specific settings. `SET FROM CURRENT` saves the session's current value of the parameter as the role-specific value. If `IN DATABASE` is specified, the configuration parameter is set or removed for the given role and database only.

Role-specific variable settings take effect only at login; SET ROLE and SET SESSION AUTHORIZATION do not process role-specific variable settings.

See SET and Server Configuration Parameters for more information about allowed parameter names and values.

group_name The name of the resource group to assign to this role. Specifying the group_name `NONE` removes the role's current resource group assignment and assigns a default resource group based on the role's capability. `SUPERUSER` roles are assigned the `admin_group` resource group, while the `default_group` resource group is assigned to non-admin roles.

You cannot assign a resource group that you create for an external component to a role.

queue_name The name of the resource queue to which the user-level role is to be assigned. Only roles with `LOGIN` privilege can be assigned to a resource queue. To unassign a role from a resource queue and put it in the default resource queue, specify `NONE`. A role can belong only to one resource queue.

Notes

Use CREATE ROLE to add a new role, and DROP ROLE to remove a role.

`ALTER ROLE` cannot change a role's memberships; use GRANT and REVOKE to do that.

You must exercise caution when specifying an unencrypted password with this command. The password will be transmitted to the server in clear text, and it might also be logged in the client's command history or the server log. The psql command-line client contains a meta-command `\password` that can be used to change a role's password without exposing the clear text password.

It is also possible to tie a session default to a specific database rather than to a role; see ALTER DATABASE. If there is a conflict, database-role-specific settings override role-specific ones, which in turn override database-specific ones.

Examples

Change the password for a role:

```
ALTER ROLE daria WITH PASSWORD 'passwd123';
```

Remove a role's password:

```
ALTER ROLE daria WITH PASSWORD NULL;
```

Change a password expiration date, specifying that the password should expire at midday on 4th May 2022 using the time zone which is one hour ahead of UTC:

```
ALTER ROLE scott VALID UNTIL 'May 4 12:00:00 2022 +1';
```

Make a password valid forever:

```
ALTER ROLE luke VALID UNTIL 'infinity';
```

Give a role the ability to create other roles and new databases:

```
ALTER ROLE joelle CREATEROLE CREATEDB;
```

Give a role a non-default setting of the `maintenance_work_mem` parameter:

```
ALTER ROLE admin SET maintenance_work_mem = 100000;
```

Give a role a non-default, database-specific setting of the `client_min_messages` parameter:

```
ALTER ROLE fred IN DATABASE devel SET client_min_messages = DEBUG;
```

Assign a role to a resource queue:

```
ALTER ROLE sammy RESOURCE QUEUE poweruser;
```

Give a role permission to create writable external tables:

```
ALTER ROLE load CREATEEXTTABLE (type='writable');
```

Alter a role so it does not allow login access on Sundays:

```
ALTER ROLE user3 DENY DAY 'Sunday';
```

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Alter a role to remove the constraint that does not allow login access on Sundays:

```
ALTER ROLE user3 DROP DENY FOR DAY 'Sunday';
```

Assign a new resource group to a role:

```
ALTER ROLE parttime_user RESOURCE GROUP rg_light;
```

Compatibility

The `ALTER ROLE` statement is a WarehousePG extension.

See Also

CREATE ROLE, DROP ROLE, ALTER DATABASE, SET, CREATE RESOURCE GROUP, CREATE RESOURCE QUEUE, GRANT, REVOKE

Parent topic: SQL Commands

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7.1.26 ALTER ROUTINE

Changes the definition of a routine.

Synopsis

```
ALTER ROUTINE <name> [ ( [ [<argmode>] [<argname>] <argtype> [, ...] ] ) ]
   <action> [, ... ] [RESTRICT]

ALTER ROUTINE <name> [ ( [ [<argmode>] [<argname>] <argtype> [, ...] ] ) ]
   RENAME TO <new_name>

ALTER ROUTINE <name> [ ( [ [<argmode>] [<argname>] <argtype> [, ...] ] ) ]
   OWNER TO { <new_owner> | CURRENT_USER | SESSION_USER }

ALTER ROUTINE <name> [ ( [ [<argmode>] [<argname>] <argtype> [, ...] ] ) ]
   SET SCHEMA <new_schema>

ALTER ROUTINE <name> [ ( [ [<argmode>] [<argname>] <argtype> [, ...] ] ) ]
   DEPENDS ON EXTENSION <extension_name>

where <action> is one of (depending on the type of routine):

    { IMMUTABLE | STABLE | VOLATILE }
    [ NOT ] LEAKPROOF
    { [EXTERNAL] SECURITY INVOKER | [EXTERNAL] SECURITY DEFINER }
    PARALLEL { UNSAFE | RESTRICTED | SAFE }
    EXECUTE ON { ANY | COORDINATOR | ALL SEGMENTS | INITPLAN }
    COST <execution_cost>
    ROWS <result_rows>
    SET <configuration_parameter> { TO | = } { <value> | DEFAULT }
    SET <configuration_parameter> FROM CURRENT
    RESET <configuration_parameter>
    RESET ALL
```

Description

`ALTER ROUTINE` changes the definition of a routine, which can be an aggregate function, a normal function, or a procedure. Refer to ALTER AGGREGATE, ALTER FUNCTION, and ALTER PROCEDURE for the description of the parameters, more examples, and further details.

Examples

To rename the routine `foo` for type `integer` to `foobar`:

```
ALTER ROUTINE foo(integer) RENAME TO foobar;
```

This command will work independent of whether `foo` is an aggregate, function, or procedure.

Compatibility

This statement is partially compatible with the `ALTER ROUTINE` statement in the SQL standard. Refer to ALTER FUNCTION and ALTER PROCEDURE for more details. Allowing routine names to refer to aggregate functions is a WarehousePG extension.

See Also

ALTER AGGREGATE, ALTER FUNCTION, ALTER PROCEDURE, DROP ROUTINE

Parent topic: SQL Commands

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7.1.27 ALTER SCHEMA

Changes the definition of a schema.

Synopsis

```
ALTER SCHEMA <name> RENAME TO <new_name>

ALTER SCHEMA <name> OWNER TO { <new_owner> | CURRENT_USER | SESSION_USER }
```

Description

`ALTER SCHEMA` changes the definition of a schema.

You must own the schema to use `ALTER SCHEMA`. To rename a schema you must also have the `CREATE` privilege for the database. To alter the owner, you must also be a direct or indirect member of the new owning role, and you must have the `CREATE` privilege for the database. Note that superusers have all these privileges automatically.

Parameters

name The name of an existing schema.

new*name The new name of the schema. The new name cannot begin with `pg`*, as such names are reserved for system schemas.

new_owner The new owner of the schema.

Compatibility

There is no `ALTER SCHEMA` statement in the SQL standard.

See Also

CREATE SCHEMA, DROP SCHEMA

Parent topic: SQL Commands

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7.1.28 ALTER SEQUENCE

Changes the definition of a sequence generator.

Synopsis

```
ALTER SEQUENCE [ IF EXISTS ] <name>
     [ AS <data_type> ]
     [INCREMENT [ BY ] <increment>]
     [MINVALUE <minvalue> | NO MINVALUE]
     [MAXVALUE <maxvalue> | NO MAXVALUE]
     [START [ WITH ] <start> ]
     [RESTART [ [ WITH ] <restart>] ]
     [CACHE <cache>] [[ NO ] CYCLE]
     [OWNED BY {<table_name.column_name> | NONE}]

ALTER SEQUENCE [ IF EXISTS ] <name> OWNER TO { <new_owner> | CURRENT_USER | SESSION_USER }

ALTER SEQUENCE [ IF EXISTS ] <name> RENAME TO <new_name>

ALTER SEQUENCE [ IF EXISTS ] <name> SET SCHEMA <new_schema>
```

Description

`ALTER SEQUENCE` changes the parameters of an existing sequence generator. Any parameters not specifically set in the `ALTER SEQUENCE` command retain their prior settings.

You must own the sequence to use `ALTER SEQUENCE`. To change a sequence's schema, you must also have `CREATE` privilege on the new schema. Note that superusers have all these privileges automatically.

To alter the owner, you must be a direct or indirect member of the new owning role, and that role must have `CREATE` privilege on the sequence's schema. (These restrictions enforce that altering the owner does not do anything you could not do by dropping and recreating the sequence. However, a superuser can alter ownership of any sequence anyway.)

Parameters

name The name (optionally schema-qualified) of a sequence to be altered.

IF EXISTS Do not throw an error if the sequence does not exist. WarehousePG issues a notice in this case.

data_type The optional clause `AS data_type` changes the data type of the sequence. Valid types are `smallint`, `integer`, and `bigint`.

Changing the data type automatically changes the minimum and maximum values of the sequence if and only if the previous minimum and maximum values were the minimum or maximum value of the old data type (in other words, if the sequence had been created using `NO MINVALUE` or `NO MAXVALUE`, implicitly or explicitly). Otherwise, the minimum and maximum values are preserved, unless new values are given as part of the same command. If the minimum and maximum values do not fit into the new data type, WarehousePG generates an error.

increment The clause `INCREMENT BY increment` is optional. A positive value will make an ascending sequence, a negative one a descending sequence. If unspecified, the old increment value will be maintained.

minvalue NO MINVALUE The optional clause `MINVALUE minvalue` determines the minimum value a sequence can generate. If `NO MINVALUE` is specified, the defaults of `1` and the minimum value of the data type for ascending and descending sequences, respectively, will be used. If neither option is specified, the current minimum value will be maintained.

maxvalue NO MAXVALUE The optional clause `MAXVALUE maxvalue` determines the maximum value for the sequence. If `NO MAXVALUE` is specified, the defaults of the maximum value of the data type and `-1` for ascending and descending sequences, respectively, will be used. If neither option is specified, the current maximum value will be maintained.

start The optional clause `START WITH start` changes the recorded start value of the sequence. This has no effect on the *current* sequence value; it simply sets the value that future `ALTER SEQUENCE RESTART` commands will use.

restart The optional clause `RESTART [ WITH restart ]` changes the current value of the sequence. This is equivalent to calling the `setval(sequence, start_val, is_called)` function with `is_called = false`. The specified value will be returned by the *next* call of the `nextval(sequence)` function. Writing `RESTART` with no restart value is equivalent to supplying the start value that was recorded by `CREATE SEQUENCE` or last set by `ALTER SEQUENCE START WITH`. In contrast to a `setval()` call, a `RESTART` operation on a sequence is transactional and blocks concurrent transactions from obtaining numbers from the same sequence. If that's not the desired mode of operation, `setval()` should be used

cache The clause `CACHE cache` enables sequence numbers to be preallocated and stored in memory for faster access. The minimum value is 1 (only one value can be generated at a time, i.e., no cache). If unspecified, the old cache value will be maintained.

> **Note** When operating with a cache of sequence numbers (`cache > 1`), WarehousePG may discard some cached sequence values. If you require consecutive values, you must explicitly set `CACHE 1` when you create or alter the sequence.

CYCLE The optional `CYCLE` key word may be used to enable the sequence to wrap around when the `maxvalue` or `minvalue` has been reached by an ascending or descending sequence. If the limit is reached, the next number generated will be the respective `minvalue` or `maxvalue`.

NO CYCLE If the optional `NO CYCLE` key word is specified, any calls to `nextval()` after the sequence has reached its maximum value will return an error. If neither `CYCLE` or `NO CYCLE` are specified, the old cycle behavior will be maintained.

OWNED BY table_name.column_name OWNED BY NONE The `OWNED BY` option causes the sequence to be associated with a specific table column, such that if that column (or its whole table) is dropped, the sequence will be automatically dropped as well. If specified, this association replaces any previously specified association for the sequence. The specified table must have the same owner and be in the same schema as the sequence. Specifying `OWNED BY NONE` removes any existing table column association.

new_owner The user name of the new owner of the sequence.

new_name The new name for the sequence.

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new_schema The new schema for the sequence.

Notes

`ALTER SEQUENCE` will not immediately affect `nextval()` results in backends, other than the current one, that have preallocated (cached) sequence values. They will use up all cached values prior to noticing the changed sequence generation parameters. The current backend will be affected immediately.

`ALTER SEQUENCE` blocks concurrent `nextval()` and `setval()` calls.

For historical reasons, `ALTER TABLE` can be used with sequences too; but the only variants of `ALTER TABLE` that are allowed with sequences are equivalent to the forms shown above.

Examples

Restart a sequence called `serial` at `105`:

```
ALTER SEQUENCE serial RESTART WITH 105;
```

Compatibility

`ALTER SEQUENCE` conforms to the SQL standard, except for the `AS`, `START WITH`, `OWNED BY`, `OWNER TO`, `RENAME TO`, and `SET SCHEMA` clauses, which are WarehousePG extensions.

See Also

CREATE SEQUENCE, DROP SEQUENCE, ALTER TABLE

Parent topic: SQL Commands

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7.1.29 ALTER SERVER

Changes the definition of a foreign server.

Synopsis

```
ALTER SERVER <name> [ VERSION '<new_version>' ]
    [ OPTIONS ( [ ADD | SET | DROP ] <option> ['<value>'] [, ... ] ) ]

ALTER SERVER <name> OWNER TO { <new_owner> | CURRENT_USER | SESSION_USER }

ALTER SERVER <name> RENAME TO <new_name>
```

Description

`ALTER SERVER` changes the definition of a foreign server. The first form of the command changes the version string or the generic options of the server. WarehousePG requires at least one clause. The second and third forms of the command change the owner or the name of the server.

To alter the server, you must be the owner of the server. To alter the owner you must:

- Own the server.
- Be a direct or indirect member of the new owning role.
- Have `USAGE` privilege on the server's foreign-data wrapper.

Superusers automatically satisfy all of these criteria.

Parameters

name The name of an existing server.

new_version The new server version.

OPTIONS ([ADD | SET | DROP] option ['value'] [, ...]) Change the server's options `ADD`, `SET`, and `DROP` specify the action to perform. Option names must be unique. WarehousePG validates names and values using the server's foreign-data wrapper library. Use `ADD` to define an option that is not currently set. Use `SET` to change the value of an option that you previously defined. If you do not explicitly specify an action, the default operation is `ADD`.

new_owner Specifies the new owner of the foreign server.

new_name Specifies the new name of the foreign server.

Examples

Change the definition of a server named `foo` by adding connection options:

```
ALTER SERVER foo OPTIONS (host 'foo', dbname 'foodb');
```

Change the option named `host` for a server named `foo`, and set the server version:

```
ALTER SERVER foo VERSION '9.1' OPTIONS (SET host 'baz');
```

Compatibility

`ALTER SERVER` conforms to ISO/IEC 9075-9 (SQL/MED). The `OWNER TO` and `RENAME` forms are WarehousePG extensions.

See Also

CREATE SERVER, DROP SERVER

Parent topic: SQL Commands

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7.1.30 ALTER STATISTICS

Changes the definition of an extended statistics object.

Synopsis

```
ALTER STATISTICS <name> RENAME TO <new_name>

ALTER STATISTICS <name> OWNER TO { <new_owner> | CURRENT_USER | SESSION_USER }

ALTER STATISTICS <name> SET SCHEMA <new_schema>
```

Description

`ALTER STATISTICS` changes the parameters of an existing extended statistics object. Any parameters not specifically set in the `ALTER STATISTICS` command retain their prior settings.

You must own the statistics object to use `ALTER STATISTICS`. To change a statistics object's schema, you must also have `CREATE` privilege on the new schema. To alter the owner, you must also be a direct or indirect member of the new owning role, and that role must have `CREATE` privilege on the statistics object's schema. (These restrictions enforce that altering the owner doesn't do anything you couldn't do by dropping and recreating the statistics object. However, a superuser can alter ownership of any statistics object anyway.)

Parameters

name The name (optionally schema-qualified) of the statistics object to be altered.

new_owner The user name of the new owner of the statistics object.

new_name The new name for the statistics object.

new_schema The new schema for the statistics object.

Compatibility

There is no `ALTER STATISTICS` statement in the SQL standard.

See Also

CREATE STATISTICS, DROP STATISTICS

Parent topic: SQL Commands

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7.1.31 ALTER TABLE

Changes the definition of a table.

Synopsis

```
ALTER TABLE [IF EXISTS] [ONLY] <name> [ * ]
    <action> [, ... ]

ALTER TABLE [IF EXISTS] [ONLY] <name> [ * ]
    RENAME [COLUMN] <column_name> TO <new_column_name>

ALTER TABLE [IF EXISTS] [ ONLY ] <name> [ * ]
    RENAME CONSTRAINT <constraint_name> TO <new_constraint_name>

ALTER TABLE [IF EXISTS] <name>
    RENAME TO <new_name>

ALTER TABLE [IF EXISTS] <name>
    SET SCHEMA <new_schema>

ALTER TABLE ALL IN TABLESPACE <name> [ OWNED BY <role_name> [, ... ] ]
    SET TABLESPACE <new_tablespace> [ NOWAIT ]

ALTER TABLE [ IF EXISTS ] <name>
    ATTACH PARTITION <partition_name> { FOR VALUES <partition_bound_spec> | DEFAULT }

ALTER TABLE [ IF EXISTS ] <name>
    DETACH PARTITION <partition_name>

ALTER TABLE [IF EXISTS] [ONLY] <name> SET
   [ WITH (reorganize={ true | false }) ]
     DISTRIBUTED BY ({<column_name> [<opclass>]} [, ... ] )
   | DISTRIBUTED RANDOMLY
   | DISTRIBUTED REPLICATED

where <action> is one of:

  ADD [COLUMN] [IF NOT EXISTS] <column_name> <data_type> [ COLLATE <collation> ] [<column_constraint> [ ... ]]
      [ ENCODING ( <storage_directive> [,...] ) ]
  DROP [COLUMN] [IF EXISTS] <column_name> [RESTRICT | CASCADE]
  ALTER [COLUMN] <column_name> [ SET DATA ] TYPE <data_type> [COLLATE <collation>] [USING <expression>]
  ALTER [COLUMN] <column_name> SET DEFAULT <expression>
  ALTER [COLUMN] <column_name> DROP DEFAULT
  ALTER [COLUMN] <column_name> { SET | DROP } NOT NULL
  ALTER [COLUMN] <column_name> ADD GENERATED { ALWAYS | BY DEFAULT } AS IDENTITY [ ( <sequence_options> ) ]
  ALTER [COLUMN] <column_name> { SET GENERATED { ALWAYS | BY DEFAULT }
       | SET <sequence_option>
       | RESTART [ [ WITH ] <restart> ] } [...]
  ALTER [COLUMN] <column_name> DROP IDENTITY [ IF EXISTS ]
  ALTER [COLUMN] <column_name> SET STATISTICS <integer>
  ALTER [COLUMN] <column_name> SET ( <attribute_option> = <value> [, ... ] )
  ALTER [COLUMN] <column_name> RESET ( <attribute_option> [, ... ] )
  ALTER [COLUMN] <column_name> SET STORAGE { PLAIN | EXTERNAL | EXTENDED | MAIN }
  ALTER [COLUMN] <column_name> SET ENCODING ( storage_directive> [, ...] )
  ADD <table_constraint> [NOT VALID]
  ADD <table_constraint_using_index>
  ALTER CONSTRAINT <constraint_name> [ DEFERRABLE | NOT DEFERRABLE ] [ INITIALLY DEFERRED | INITIALLY IMMEDIATE ]
  VALIDATE CONSTRAINT <constraint_name>
  DROP CONSTRAINT [IF EXISTS] <constraint_name> [RESTRICT | CASCADE]
  DISABLE ROW LEVEL SECURITY
  ENABLE ROW LEVEL SECURITY
  FORCE ROW LEVEL SECURITY
  NO FORCE ROW LEVEL SECURITY
  CLUSTER ON <index_name>
  REPACK BY COLUMNS (<colum_name_1> [ASC|DESC], <column_name_2> [ASC|DESC], ...)
  SET WITHOUT CLUSTER
  SET WITHOUT OIDS
  SET TABLESPACE <new_tablespace>
  SET { LOGGED | UNLOGGED }
  SET ( <storage_parameter> [= <value>] [, ...])
  SET WITH (<set_with_parameter> = <value> [, ...])
  SET ACCESS METHOD <access_method>  [WITH ( <storage_parameter> = <value>, [, ...] )]
  RESET (<storage_parameter> [, ... ])
  INHERIT <parent_table>
  NO INHERIT <parent_table>
  OF <type_name>
  NOT OF
  OWNER TO { <new_owner> | CURRENT_USER | SESSION_USER }

and <partition_bound_spec> is:

  IN ( <partition_bound_expr> [, ...] ) |
  FROM ( { <partition_bound_expr> | MINVALUE | MAXVALUE } [, ...] )
    TO ( { <partition_bound_expr> | MINVALUE | MAXVALUE } [, ...] ) |
  WITH ( MODULUS <numeric_literal>, REMAINDER <numeric_literal> )

and <column_constraint> is:
```

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```
  [ CONSTRAINT <constraint_name>]
  { NOT NULL
    | NULL
    | CHECK  ( <expression> ) [ NO INHERIT ]
    | DEFAULT <default_expr>
    | GENERATED ALWAYS AS ( <generation_expr> ) STORED
    | GENERATED { ALWAYS | BY DEFAULT } AS IDENTITY [ ( <sequence_options> ) ]
    | UNIQUE <index_parameters>
    | PRIMARY KEY <index_parameters>
    | REFERENCES <reftable> [ ( refcolumn ) ] [ MATCH FULL | MATCH PARTIAL | MATCH SIMPLE ]
        [ ON DELETE <referential_action> ] [ ON UPDATE <referential_action> ] }
  [ DEFERRABLE | NOT DEFERRABLE ] [ INITIALLY DEFERRED | INITIALLY IMMEDIATE ]

and <table_constraint> is:

  [ CONSTRAINT <constraint_name> ]
  { CHECK ( <expression> ) [ NO INHERIT ]
    | UNIQUE ( <column_name> [, ... ] ) <index_parameters>
    | PRIMARY KEY ( <column_name> [, ... ] ) <index_parameters>
    | EXCLUDE [ USING <index_method> ] ( <exclude_element> WITH <operator> [, ... ] )
        <index_parameters> [ WHERE ( <predicate> ) ]
    | FOREIGN KEY ( <column_name> [, ... ] ) REFERENCES <reftable> [ ( <refcolumn> [, ... ] ) ]
        [ MATCH FULL | MATCH PARTIAL | MATCH SIMPLE ] [ ON DELETE <referential_action> ] [ ON UPDATE <referential_action> ] }
  [ DEFERRABLE | NOT DEFERRABLE ] [ INITIALLY DEFERRED | INITIALLY IMMEDIATE ]

and <table_constraint_using_index> is:

  [ CONSTRAINT <constraint_name> ]
  { UNIQUE | PRIMARY KEY } USING INDEX <index_name>
  [ DEFERRABLE | NOT DEFERRABLE ] [ INITIALLY DEFERRED | INITIALLY IMMEDIATE ]

and <index_parameters> in UNIQUE, PRIMARY KEY, and EXCLUDE constraints are:

  [ INCLUDE ( <column_name> [, ... ] ) ]
  [ WITH ( <storage_parameter> [=<value>] [, ... ] ) ]
  [ USING INDEX TABLESPACE <tablespace_name> ]

and <exclude_element> in an EXCLUDE constraint is:

  { <column_name> | ( <expression> ) } [ <opclass> ] [ ASC | DESC ]
     [ NULLS { FIRST | LAST }

and <set_with_parameter> is:

   reorganize={ true | false } |
   orientation={COLUMN|ROW}
   appendoptimized={ true | false } [, <storage_parameter> [, ...]]
```

Classic partitioning syntax elements include:

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```
ALTER TABLE <name>
   [ ALTER PARTITION { <partition_name> | FOR (<value>) } [...] ] <partition_action>

where <partition_action> is one of:

  ALTER DEFAULT PARTITION
  DROP DEFAULT PARTITION [IF EXISTS]
  DROP PARTITION [IF EXISTS] { <partition_name> |
      FOR (<value>) } [CASCADE]
  TRUNCATE DEFAULT PARTITION
  TRUNCATE PARTITION { <partition_name> | FOR (<value>) }
  RENAME DEFAULT PARTITION TO <new_partition_name>
  RENAME PARTITION { <partition_name> | FOR (<value>) } TO <new_partition_name>
  ADD DEFAULT PARTITION <name> [ ( <subpartition_spec> ) ]
  ADD PARTITION [<partition_name>] <partition_element>
     [ ( <subpartition_spec> ) ]
  EXCHANGE PARTITION { <partition_name> | FOR (<value>) } WITH TABLE <table_name>
        [ WITH | WITHOUT VALIDATION ]
  EXCHANGE DEFAULT PARTITION WITH TABLE <table_name>
   [ WITH | WITHOUT VALIDATION ]
  SET SUBPARTITION TEMPLATE (<subpartition_spec>)
  SPLIT DEFAULT PARTITION
    {  AT (<list_value>)
     | START([<datatype>] <range_value>) [INCLUSIVE | EXCLUSIVE]
        END([<datatype>] <range_value>) [INCLUSIVE | EXCLUSIVE] }
    [ INTO ( PARTITION <new_partition_name>,
             PARTITION <default_partition_name> ) ]
  SPLIT PARTITION { <partition_name> | FOR (<value>) } AT (<value>)
    [ INTO (PARTITION <partition_name>, PARTITION <partition_name>)]

and <partition_element> is:

    VALUES (<list_value> [,...] )
  | START ([<datatype>] '<start_value>') [INCLUSIVE | EXCLUSIVE]
     [ END ([<datatype>] '<end_value>') [INCLUSIVE | EXCLUSIVE] ]
  | END ([<datatype>] '<end_value>') [INCLUSIVE | EXCLUSIVE]
[ WITH ( <storage_parameter> = value> [ , ... ] ) ]
[ TABLESPACE <tablespace> ]

and <subpartition_spec> is:

<subpartition_element> [, ...]

and <subpartition_element> is:

   DEFAULT SUBPARTITION <subpartition_name>
  | [SUBPARTITION <subpartition_name>] VALUES (<list_value> [,...] )
  | [SUBPARTITION <subpartition_name>]
     START ([<datatype>] '<start_value>') [INCLUSIVE | EXCLUSIVE]
     [ END ([<datatype>] '<end_value>') [INCLUSIVE | EXCLUSIVE] ]
     [ EVERY ( [<number | datatype>] '<interval_value>') ]
  | [SUBPARTITION <subpartition_name>]
     END ([<datatype>] '<end_value>') [INCLUSIVE | EXCLUSIVE]
     [ EVERY ( [<number | datatype>] '<interval_value>') ]
[ WITH ( <storage_parameter>=<value> [, ... ] ) ]
[ TABLESPACE <tablespace> ]
```

Description

`ALTER TABLE` changes the definition of an existing table. There are several subforms described below. Note that the lock level required may differ for each subform.*An `ACCESS EXCLUSIVE` lock is acquired unless explicitly noted.* When multiple subcommands are provided, WarehousePG acquires the strictest lock required by any subcommand.

ADD COLUMN [IF NOT EXISTS] Adds a new column to the table, using the same syntax asCREATE TABLE. If `IF NOT EXISTS` is specified and a column already exists with this name, no error is thrown.

DROP COLUMN [IF EXISTS] Drops a column from a table. Note that if you drop table columns that are being used as the WarehousePG distribution key, the distribution policy for the table will be changed tc `DISTRIBUTED RANDOMLY` . Indexes and table constraints involving the column are automatically dropped as well. Multivariate statistics referencing the dropped column will also be removed if the removal of the column would cause the statistics to contain data for only a single column. You need to specify `CASCADE` if anything outside of the table depends on the column, such as views. If `IF EXISTS` is specified and the column does not exist, no error is thrown; WarehousePG issues a notice instead.

SET DATA TYPE This form changes the data type of a column of a table. Note that you cannot alter column data types that are being used as distribution or partitioning keys. Indexes and simple table constraints involving the column will be automatically converted to use the new column type by reparsing the originally supplied expression. The optional `COLLATE` clause specifies a collation for the new column; if omitted, the collation is the default for the new column type. The optional `USING` clause specifies how to compute the new column value from the old. If omitted, the default conversion is the same as an assignment cast from old data type to new. A `USING` clause must be provided if there is no implicit or assignment cast from old to new type.

> **Note** The WarehousePG query optimizer (GPORCA) supports collation only when all columns in the query use the same collation. If columns in the query use different collations, then WarehousePG uses the Postgres-based planner.

Changing a column data type may or may not require a table rewrite. For information about table rewrites performed by `ALTER TABLE` , see Notes.

SET DEFAULT DROP DEFAULT Sets or removes the default value for a column. Default values apply only in subsequent `INSERT` or `UPDATE` commands; they do not cause rows already in the table to change.

SET NOT NULL DROP NOT NULL Changes whether a column is marked to allow null values or to reject null values.

`SET NOT NULL` may only be applied to a column provided none of the records in the table contain a `NULL` value for the column. This is typically checked during the `ALTER TABLE` by scanning the entire table; however, if a valid `CHECK` constraint is found which proves no `NULL` can exist, then WarehousePG skips the table scan.

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If this table is a partition, you cannot `DROP NOT NULL` on a column if it is marked `NOT NULL` in the parent table. To drop the `NOT NULL` constraint from all the partitions, perform `DROP NOT NULL` on the parent table. Even if there is no `NOT NULL` constraint on the parent, such a constraint can still be added to individual partitions, if desired; that is, the children can disallow nulls even if the parent allows them, but not the other way around.

ADD GENERATED { ALWAYS | BY DEFAULT } AS IDENTITY SET GENERATED { ALWAYS | BY DEFAULT } DROP IDENTITY [IF EXISTS] These forms change whether a column is an identity column or change the generation attribute of an existing identity column. See CREATE TABLE for details.

If `DROP IDENTITY IF EXISTS` is specified and the column is not an identity column, no error is thrown. In this case WarehousePG issues a notice instead.

SET sequence_option RESTART These forms alter the sequence that underlies an existing identity column. sequence_option is an option supported by ALTER SEQUENCE such as `INCREMENT BY`.

SET STATISTICS Sets the per-column statistics-gathering target for subsequent ANALYZE operations. The target can be set in the range 0 to 10000, or set to -1 to revert to using the system default statistics target (default_statistics_target. When set to 0, no statistics are collected.

`SET STATISTICS` acquires a `SHARE UPDATE EXCLUSIVE` lock.

SET (attribute_option = value [, ...]) RESET (attribute_option [, ...]) Sets or resets per-attribute options. Currently, the only defined per-attribute options are `n_distinct` and `n_distinct_inherited`, which override the number-of-distinct-values estimates made by subsequent ANALYZE operations. `n_distinct` affects the statistics for the table itself, while `n_distinct_inherited` affects the statistics gathered for the table plus its inheritance children. When set to a positive value, `ANALYZE` assumes that the column contains exactly the specified number of distinct non-null values. When set to a negative value, which must be greater than or equal to -1, `ANALYZE` assumes that the number of distinct non-null values in the column is linear in the size of the table; the exact count is to be computed by multiplying the estimated table size by the absolute value of the given number. For example, a value of -1 implies that all values in the column are distinct, while a value of -0.5 implies that each value appears twice on the average. This can be useful when the size of the table changes over time, since the multiplication by the number of rows in the table is not performed until query planning time. Specify the value 0 to revert to estimating the number of distinct values normally.

Changing per-attribute options acquires a `SHARE UPDATE EXCLUSIVE` lock.

Do not use this form of `SET` to set attribute encoding options for appendoptimized, column-oriented tables. Instead, use `ALTER COLUMN ... SET ENCODING ...`.

SET STORAGE This form sets the storage mode for a column. This controls whether this column is held inline or in a secondary TOAST table, and whether the data should be compressed or not. `PLAIN` must be used for fixed-length values such as integer and is inline, uncompressed. `MAIN` is for inline, compressible data. `EXTERNAL` is for external, uncompressed data, and `EXTENDED` is for external, compressed data. `EXTENDED` is the default for most data types that support non- `PLAIN` storage. Use of `EXTERNAL` will make substring operations on very large text and bytea values run faster, at the penalty of increased storage space. Note that `SET STORAGE` doesn't itself change anything in the table, it just sets the strategy to be pursued during future table updates.

SET ENCODING (storage_directive> [, ...]) This form sets column encoding options for append-optimized, column-oriented tables.

ADD table_constraint [NOT VALID] Adds a new constraint to a table using the same syntax asCREATE TABLE. The `NOT VALID` option is currently allowed only for foreign key and `CHECK` constraints.

Normally, this form causes a scan of the table to verify that all existing rows in the table satisfy the new constraint. If the constraint is marked `NOT VALID`, WarehousePG skips the potentially-lengthy initial check to verify that all rows in the table satisfy the constraint. The constraint will still be enforced against subsequent inserts or updates (that is, they'll fail unless there is a matching row in the referenced table, in the case of foreign keys; and they'll fail unless the new row matches the specified check constraints). But the database will not assume that the constraint holds for all rows in the table, until it is validated by using the `VALIDATE CONSTRAINT` option. See the Notes for more information about using the `NOT VALID` option.

Most forms of `ADD <table_constraint>` require an `ACCESS EXCLUSIVE` lock.

Additional restrictions apply when unique or primary key constraints are added to partitioned tables; see CREATE TABLE.

ADD table_constraint_using_index This form adds a new `PRIMARY KEY` or `UNIQUE` constraint to a table based on an existing unique index. All the columns of the index will be included in the constraint.

The index cannot have expression columns nor be a partial index. Also, it must be a b-tree index with default sort ordering. These restrictions ensure that the index is equivalent to one that would be built by a regular `ADD PRIMARY KEY` or `ADD UNIQUE` command.

If `PRIMARY KEY` is specified, and the index's columns are not already marked `NOT NULL`, then this command attempts to `ALTER COLUMN SET NOT NULL` against each such column. That requires a full table scan to verify the column(s) contain no nulls. In all other cases, this is a fast operation.

If a constraint name is provided then WarehousePG renames the index to match the constraint name. Otherwise the constraint will be named the same as the index.

After this command is executed, the index is "owned" by the constraint, in the same way as if the index had been built by a regular `ADD PRIMARY KEY` or `ADD UNIQUE` command. In particular, dropping the constraint will make the index disappear too.

This form is not currently supported on partitioned tables.

ALTER CONSTRAINT This form alters the attributes of a constraint that was previously created. Currently only foreign key constraints may be altered, which WarehousePG will accept, but not enforce.

VALIDATE CONSTRAINT This form validates a foreign key constraint that was previously created as `NOT VALID`, by scanning the table to ensure there are no rows for which the constraint is not satisfied. Nothing happens if the constraint is already marked valid. The advantage of separating validation from initial creation of the constraint is that validation requires a lesser lock on the table than constraint creation does.

This command acquires a `SHARE UPDATE EXCLUSIVE` lock.

DROP CONSTRAINT [IF EXISTS] Drops the specified constraint on a table, along with any index underlying the constraint. If `IF EXISTS` is specified and the constraint does not exist, no error is thrown. WarehousePG issues a notice in this case instead.

DISABLE ROW LEVEL SECURITY ENABLE ROW LEVEL SECURITY These forms control the application of row security policies belonging to the table. If enabled and no policies exist for the table, then WarehousePG applies a default-deny policy. Note that policies can exist for a table even if row level security is disabled - in this case, the policies will NOT be applied and the policies will be ignored. See also CREATE POLICY.

NO FORCE ROW LEVEL SECURITY FORCE ROW LEVEL SECURITY These forms control the application of row security policies belonging to the table when the user is the table owner. If enabled, row level security policies will be applied when the user is the table owner. If disabled (the default) then row level security will not be applied when the user is the table owner. See also CREATE POLICY.

CLUSTER ON Selects the default index for future CLUSTER operations. It does not actually re-cluster the table.

Changing cluster options acquires a `SHARE UPDATE EXCLUSIVE` lock.

REPACK BY COLUMNS Physically reorders a table based on one or more columns to improve physical correlation. You specify one or more columns, and an optional column order. If not specified, the default is `ASC`. The command is equivalent to the CLUSTER command, but it uses the provided column list instead of an index to determine the sorting order.

The command is especially useful for tables that are loaded in small batches. You may combine `REPACK BY COLUMNS` with most other `ALTER TABLE` commands that do not require a rewrite of the table. You may use `REPACK BY COLUMNS` to add compression or change the existing compression settings of a table while physically reordering the table, which results in better compression and storage. See Examples for more details.

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SET WITHOUT CLUSTER Removes the most recently used CLUSTER index specification from the table. This affects future cluster operations that do not specify an index.

Changing cluster options acquires a `SHARE UPDATE EXCLUSIVE` lock.

SET TABLESPACE Changes the table's tablespace to the specified tablespace and moves the data file(s) associated with the table to the new tablespace. Indexes on the table, if any, are not moved; but they can be moved separately with additional `SET TABLESPACE` commands. When applied to a partitioned table, nothing is moved, but any partitions created afterwards with `CREATE TABLE ... PARTITION OF` will use that tablespace, unless the `TABLESPACE` clause is used to override it.

All tables in the current database in a tablespace can be moved by using the `ALL IN TABLESPACE` form, which will lock all tables to be moved first and then move each one. This form also supports `OWNED BY`, which will only move tables owned by the roles specified. If the `NOWAIT` option is specified then the command will fail if it is unable to acquire all of the locks required immediately. Note that system catalogs are not moved by this command, use `ALTER DATABASE` or explicit `ALTER TABLE` invocations instead if desired. The `information_schema` relations are not considered part of the system catalogs and will be moved. See also CREATE TABLESPACE.

If changing the tablespace of a partitioned table, all child tables will also be moved to the new tablespace.

SET { LOGGED | UNLOGGED } This form changes the table from unlogged to logged or vice-versa. It cannot be applied to a temporary table.

SET (storage_\parameter [= value][, ...]) This form changes one or more table-level options. See Storage Parameters in the `CREATE TABLE` reference for details on the available parameters. Note that for heap tables, the table contents will not be modified immediately by this command; depending on the parameter, you may need to rewrite the table to get the desired effects. That can be done with VACUUM FULL, CLUSTER or one of the forms of `ALTER TABLE` that forces a table rewrite, see Notes. For append-optimized column-oriented tables, changing a storage parameter always results in a table rewrite. For planner-related parameters, changes take effect from the next time the table is locked, so currently executing queries are not affected.

WarehousePG takes a `SHARE UPDATE EXCLUSIVE` lock when setting `fillfactor`, toast and autovacuum storage parameters, and the planner parameter `parallel_workers`.

RESET (storage_parameter [, ...]) This form resets one or more table level options to their defaults. As with `SET`, a table rewrite might be required to update the table entirely.

SET WITH (`<set_with_parameter>` = `<value>` [, ...]) You can use this form of the command to reorganize the table, or to set the table access method and also optionally set storage parameters.

> **Note: Note:** Although you can specify the table's access method using the `appendoptimized` and `orientation` storage parameters, it is recommended to use use `SET ACCESS METHOD <access_method>` instead.

INHERIT parent_table Adds the target table as a new child of the specified parent table. Queries against the parent will include records of the target table. To be added as a child, the target table must already contain all of the same columns as the parent (it could have additional columns, too). The columns must have matching data types, and if they have `NOT NULL` constraints in the parent then they must also have `NOT NULL` constraints in the child.

There must also be matching child-table constraints for all `CHECK` constraints of the parent, except those marked non-inheritable (that is, created with `ALTER TABLE ... ADD CONSTRAINT ... NO INHERIT`) in the parent, which are ignored; all child-table constraints matched must not be marked non-inheritable. `UNIQUE`, `PRIMARY KEY`, and `FOREIGN KEY` constraints are not currently considered.

NO INHERIT parent_table This form removes the target table from the list of children of the specified parent table. Queries against the parent table will no longer include records drawn from the target table.

OF type_name This form links the table to a composite type as though `CREATE TABLE OF` had formed it. The table's list of column names and types must precisely match that of the composite type. The table must not inherit from any other table. These restrictions ensure that `CREATE TABLE OF` would permit an equivalent table definition.

NOT OF This form dissociates a typed table from its type.

OWNER TO Changes the owner of the table, sequence, view, materialized view, or foreign table to the specified user.

RENAME Changes the name of a table (or an index, sequence, view, materialized view, or foreign table), the name of an individual column in a table, or the name of a constraint of the table. When renaming a constraint that has an underlying index, the index is renamed as well. There is no effect on the stored data.

SET SCHEMA Moves the table into another schema. Associated indexes, constraints, and sequences owned by table columns are moved as well.

SET DISTRIBUTED Changes the distribution policy of a table. Changing a hash distribution policy, or changing to or from a replicated policy, will cause the table data to be physically redistributed on disk, which can be resource intensive. If you declare the same hash distribution policy or change from hash to random distribution, data will not be redistributed unless you declare `SET WITH (reorganize=true)`.

: While WarehousePG permits changing the distribution policy of a writable external table, the operation never results in physical redistribution of the external data.

ATTACH PARTITION partition_name { FOR VALUES partition_bound_spec | DEFAULT } This form of the *modern partitioning syntax* attaches an existing table (which might itself be partitioned) as a partition of the target table. The table can be attached as a partition for specific values using `FOR VALUES` or as a default partition by using `DEFAULT`. For each index in the target table, a corresponding one will be created in the attached table; or, if an equivalent index already exists, it will be attached to the target table's index, as if you had run `ALTER INDEX ATTACH PARTITION`. Note that if the existing table is a foreign table, WarehousePG does not permit attaching the table as a partition of the target table if there are `UNIQUE` indexes on the target table. (See also CREATE FOREIGN TABLE.)

A partition using `FOR VALUES` uses the same syntax for partition_bound_spec> as CREATE TABLE. The partition bound specification must correspond to the partitioning strategy and partition key of the target table. The table to be attached must have all the same columns as the target table and no more; moreover, the column types must also match. Also, it must have all of the `NOT NULL` and `CHECK` constraints of the target table. Currently `FOREIGN KEY` constraints are not considered. `UNIQUE` and `PRIMARY KEY` constraints from the parent table will be created in the partition, if they don't already exist. If any of the `CHECK` constraints of the table being attached are marked `NO INHERIT`, the command will fail; such constraints must be recreated without the `NO INHERIT` clause.

If the new partition is a regular table, WarehousePG performs a full table scan to check that existing rows in the table do not violate the partition constraint. It is possible to avoid this scan by adding a valid `CHECK` constraint to the table that allows only rows satisfying the desired partition constraint before running this command. The `CHECK` constraint will be used to determine that the table need not be scanned to validate the partition constraint. This does not work, however, if any of the partition keys is an expression and the partition does not accept `NULL` values. If attaching a list partition that will not accept `NULL` values, also add a `NOT NULL` constraint to the partition key column, unless it's an expression.

If the new partition is a foreign table, nothing is done to verify that all of the rows in the foreign table obey the partition constraint. (See the discussion in CREATE FOREIGN TABLE about constraints on the foreign table.)

When a table has a default partition, defining a new partition changes the partition constraint for the default partition. The default partition can't contain any rows that would need to be moved to the new partition, and will be scanned to verify that none are present. This scan, like the scan of the new partition, can be avoided if an appropriate `CHECK` constraint is present. Also like the scan of the new partition, it is always skipped when the default partition is a foreign table.

Attaching a partition acquires a `SHARE UPDATE EXCLUSIVE` lock on the parent table, in addition to the `ACCESS EXCLUSIVE` locks on the table being attached and on the default partition (if any). You can run `SELECT` and `INSERT` queries in parallel with `ATTACH PARTITION`. You can also run `UPDATE` queries in parallel with `ATTACH PARTITION` when the parent table is a heap table and the Global Deadlock Detector is enabled (the gp_enable_global_deadlock_detector server configuration paramer is set to `on`).

Additional locks must also be held on all sub-partitions if the table being attached is itself a partitioned table. Likewise if the default partition is itself a partitioned table. The locking of the sub-partitions can be avoided by adding a `CHECK` constraint as described in Partitioning Large Tables.

DETACH PARTITION partition_name This form of the *modern partitioning syntax* detaches the specified partition of the target table. The detached partition continues to exist as a standalone table, but no longer has any ties to the table from which it was detached. Any indexes that were attached to the target table's indexes are detached.

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ALTER PARTITION | DROP PARTITION | RENAME PARTITION | TRUNCATE PARTITION | ADD PARTITION | SPLIT PARTITION | EXCHANGE PARTITION | SET SUBPARTITION TEMPLATE These forms of the *classic partitioning syntax* change the structure of a partitioned table. You must go through the parent table to alter one of its child tables.

> **Note** If you add a partition to a table that has sub-partition encodings, the new partition inherits the storage directives for the sub-partitions. For more information about the precedence of compression settings, seeUsing Compression.

You can combine all forms of `ALTER TABLE` that act on a single table into a list of multiple alterations to apply together, except `RENAME`, `SET SCHEMA`, `ATTACH PARTITION`, and `DETACH PARTITION`. For example, it is possible to add several columns and/or alter the type of several columns in a single command. This is particularly useful with large tables, since only one pass over the table need be made.

You must own the table to use `ALTER TABLE`. To change the schema or tablespace of a table, you must also have `CREATE` privilege on the new schema or tablespace. To add the table as a new child of a parent table, you must own the parent table as well. Also, to attach a table as a new partition of the table, you must own the table being attached. To alter the owner, you must also be a direct or indirect member of the new owning role, and that role must have `CREATE` privilege on the table's schema. To add a column or alter a column type or use the `OF` clause, you must also have `USAGE` privilege on the data type. A superuser has these privileges automatically.

You can't use `ALTER TABLE ... SET DISTRIBUTED` to change a table to `COORDINATOR ONLY` distribution, nor can you change a `COORDINATOR ONLY` table to any other distribution using `ALTER TABLE`. The `COORDINATOR ONLY` distribution policy must be defined at the time of table creation. If you need to change the distribution of a coordinator-only table, you must drop the table and recreate it using the desired distribution policy.

> **Note** Memory usage increases significantly when a table has many partitions, if a table has compression, or if the blocksize for a table is large. If the number of relations associated with the table is large, this condition can force an operation on the table to use more memory. For example, if the table is an append-optimized column-oriented table and has a large number of columns, each column is a relation. An operation that accesses all of the columns in the table allocates associated buffers. If the table has 40 columns and 100 partitions, and the columns are compressed and the blocksize is 2 MB (with a system factor of 3), the system attempts to allocate 24 GB, that is (40 ×100) × (2 ×3) MB or 24 GB.

Parameters

IF EXISTS Do not throw an error if the table does not exist. WarehousePG issues a notice in this case.

name The name (possibly schema-qualified) of an existing table to alter. If `ONLY` is specified, only that table is altered. If `ONLY` is not specified, the table and all of its descendant tables (if any) are updated. You can optionally specify `*` after the table name to explicitly indicate that descendant tables are included.

```
> **Note** Adding or dropping a column, or changing a column's type, in a parent or descendant table only is not permitted. The parent table and its descendents must always have the same columns and types.
```

column_name Name of a new or existing column. Note that WarehousePG distribution key columns must be treated with special care. Altering or dropping these columns can change the distribution policy for the table.

new_column_name New name for an existing column.

new_name New name for the table.

type Data type of the new column, or new data type for an existing column. If changing the data type of a WarehousePG distribution key column, you are only allowed to change it to a compatible type (for example, `text` to `varchar` is OK, but `text` to `int` is not).

table_constraint New table constraint for the table. Note that foreign key constraints are currently not supported in WarehousePG. Also a table is only allowed one unique constraint and the uniqueness must be within the WarehousePG distribution key.

constraint_name Name of an existing constraint to drop.

ENCODING (<storage_directive> [,...]) The `ENCODING` clause is valid only for append-optimized, column-oriented tables.

When you add a column to an append-optimized, column-oriented table, WarehousePG sets each data compression parameter for the column (`compresstype`, `compresslevel`, and `blocksize`) based on the following setting, in order of preference.

```
1.  The compression parameter setting specified in the `ALTER TABLE` command `ENCODING` clause.
2.  The table's data compression setting specified in the `WITH` clause when the table was created.
3.  The compression parameter setting specified in the server configuration parameter [gp\_default\_storage\_option](../config_params/guc-list.html).
4.  The default compression parameter value.
```

For more information about the supported `ENCODING` storage directives, refer to CREATE TABLE.

CASCADE Automatically drop objects that depend on the dropped column or constraint (for example, views referencing the column), and in turn all objects that depend on those objects.

RESTRICT Refuse to drop the column or constraint if there are any dependent objects. This is the default behavior.

index_name The name of an existing index.

storage_parameter The name of a table storage parameter. Refer to the Storage Parameters section on the `CREATE TABLE` reference page for a list of parameters.

value The new value for the a table storage parameter. This might be a number or a word, depending on the parameter.

parent_table A parent table to associate or de-associate with this table.

new_owner The role name of the new owner of the table.

new_tablespace The name of the tablespace to which the table will be moved.

new_schema The name of the schema to which the table will be moved.

partition_name The name of the table to attach as a new partition or to detach from this table.

partition_bound_spec The partition bound specification for a new partition. Refer to CREATE TABLE for more details on the syntax of the same.

access_method The method to use for accessing the table. Refer to Choosing the Storage Model for more information on the table storage models and access methods available in WarehousePG. Set to `heap` to access the table as a heap-storage table, `ao_row` to access the table as an append-optimized table with row-oriented storage (AO), or `ao_column` to access the table as an append-optimized table with column-oriented storage (AO/CO).

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> **Note: Note:** Although you can specify the table's access method using `SET <storage_parameter>`, the recommendation is to use `SET ACCESS METHOD <access_method>` instead.

SET WITH (reorganize=true|false) Use `reorganize=true` when the hash distribution policy has not changed or when you have changed from a hash to a random distribution, and you want to redistribute the data anyway. If you are setting the distribution policy, you must specify the `WITH (reorganize=<value>)` clause before the `DISTRIBUTED ...` clause.
Any attempt to reorganize an external table fails with an error.

Classic Partitioning Syntax Parameters

Descriptions of additional parameters that are specific to the *classic partitioning syntax* follow.

ALTER [DEFAULT] PARTITION If altering a partition deeper than the first level of partitions, use `ALTER PARTITION` clauses to specify which sub-partition in the hierarchy you want to alter. For each partition level in the table hierarchy that is above the target partition, specify the partition that is related to the target partition in an `ALTER PARTITION` clause.

DROP [DEFAULT] PARTITION Drops the specified partition. If the partition has sub-partitions, the sub-partitions are automatically dropped as well.

TRUNCATE [DEFAULT] PARTITION Truncates the specified partition. If the partition has sub-partitions, the sub-partitions are automatically truncated as well.

RENAME [DEFAULT] PARTITION Changes the partition name of a partition (not the relation name). Partitioned tables are created using the naming convention: `<` parentname `>_<` level `>_prt_<` partition_name `>`.

ADD DEFAULT PARTITION Adds a default partition to an existing partition design. When data does not match to an existing partition, it is inserted into the default partition. Partition designs that do not have a default partition will reject incoming rows that do not match to an existing partition. Default partitions must be given a name.

ADD PARTITION partition_element - Using the existing partition type of the table (range or list), defines the boundaries of new partition you are adding. `ADD PARTITION` acquires an `ACCESS EXCLUSIVE` lock on the parent table.

name - A name for this new partition.

VALUES - For list partitions, defines the value(s) that the partition will contain.

START - For range partitions, defines the starting range value for the partition. By default, start values are `INCLUSIVE`. For example, if you declared a start date of `2016-01-01`', then the partition would contain all dates greater than or equal to '`2016-01-01`'. The data type of the `START` expression must support a suitable `+` operator, for example `timestamp` or `integer` (not `float` or `text`) if it is defined with the `EXCLUSIVE` keyword. Typically the data type of the `START` expression is the same type as the partition key column. If that is not the case, then you must explicitly cast to the intended data type.

END - For range partitions, defines the ending range value for the partition. By default, end values are `EXCLUSIVE`. For example, if you declared an end date of `2016-02-01`', then the partition would contain all dates less than but not equal to '`2016-02-01`'. The data type of the `END` expression must support a suitable `+` operator, for example `timestamp` or `integer` (not `float` or `text`) if it is defined with the `INCLUSIVE` keyword. Typically the data type of the `END` expression is the same type as the partition key column. If that is not the case, then you must explicitly cast to the intended data type.

WITH - Sets the table storage options for a partition. For example, you may want older partitions to be append-optimized tables and newer partitions to be regular heap tables. SeeCREATE TABLE for a description of the storage options.

TABLESPACE - The name of the tablespace in which the partition is to be created.

subpartition_spec - Only allowed on partition designs that were created without a sub-partition template. Declares a sub-partition specification for the new partition you are adding. If the partitioned table was originally defined using a sub-partition template, then the template will be used to generate the sub-partitions automatically.

EXCHANGE [DEFAULT] PARTITION Exchanges another table into the partition hierarchy into the place of an existing partition. In a multi-level partition design, you can only exchange the lowest level partitions (those that contain data).

WITH TABLE table_name - The name of the table you are swapping into the partition design. You can exchange a table where the table data is stored in the database. For example, the table is created with the `CREATE TABLE` command. The table must have the same number of columns, column order, column names, column types, and distribution policy as the parent table.

With the `EXCHANGE PARTITION` clause, you can also exchange a readable external table (created with the `CREATE EXTERNAL TABLE` command) into the partition hierarchy in the place of an existing leaf partition.

Exchanging a leaf partition with an external table is not supported if the partitioned table contains a column with a check constraint or a `NOT NULL` constraint.

You cannot exchange a partition with a replicated table. Exchanging a partition with a partitioned table or a child partition of a partitioned table is not supported.

WITH | **WITHOUT VALIDATION** - No-op (always validate the data against the partition constraint).

SET SUBPARTITION TEMPLATE Modifies the sub-partition template for an existing partition. After a new sub-partition template is set, all new partitions added will have the new sub-partition design (existing partitions are not modified).

SPLIT DEFAULT PARTITION Splits a default partition. In a multi-level partition, only a range partition can be split, not a list partition, and you can only split the lowest level default partitions (those that contain data). Splitting a default partition creates a new partition containing the values specified and leaves the default partition containing any values that do not match to an existing partition.

AT - For list partitioned tables, specifies a single list value that should be used as the criteria for the split.

START - For range partitioned tables, specifies a starting value for the new partition.

END - For range partitioned tables, specifies an ending value for the new partition.

INTO - Allows you to specify a name for the new partition. When using the `INTO` clause to split a default partition, the second partition name specified should always be that of the existing default partition. If you do not know the name of the default partition, you can look it up using the pg_partitions view.

SPLIT PARTITION Splits an existing partition into two partitions. In a multi-level partition, only a range partition can be split, not a list partition, and you can only split the lowest level partitions (those that contain data).

AT - Specifies a single value that should be used as the criteria for the split. The partition will be divided into two new partitions with the split value specified being the starting range for the latter partition.

INTO - Allows you to specify names for the two new partitions created by the split.

partition_name The given name of a partition. You can obtain the table names of the leaf partitions of a partitioned table using the `pg_partition_tree() function.

FOR ('value') Specifies a partition by declaring a value that falls within the partition boundary specification. If the value declared with `FOR` matches to both a partition and one of its sub-partitions (for example, if the value is a date and the table is partitioned by month and then by day), then `FOR` will operate on the first level where a match is found (for example, the monthly partition). If your intent is to operate on a sub-partition, you must declare so as follows:
`ALTER TABLE name ALTER PARTITION FOR ('2016-10-01') DROP PARTITION FOR ('2016-10-01');`

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Notes

The key word `COLUMN` is noise and can be omitted.

When a column is added with `ADD COLUMN`, all existing rows in the table are initialized with the column's default value, or `NULL` if no `DEFAULT` clause is specified. Adding a column with a non-null default or changing the type of an existing column will require the entire table and indexes to be rewritten. As an exception, if the `USING` clause does not change the column contents and the old type is either binary coercible to the new type or an unconstrained domain over the new type, a table rewrite is not needed, but any indexes on the affected columns must still be rebuilt. Table and/or index rebuilds may take a significant amount of time for a large table; and will temporarily require as much as double the disk space.

Adding a `CHECK` or `NOT NULL` constraint requires scanning the table to verify that existing rows meet the constraint, but does not require a table rewrite.

Similarly, when attaching a new partition it may be scanned to verify that existing rows meet the partition constraint.

WarehousePG provides the option to specify multiple changes in a single `ALTER TABLE` so that multiple table scans or rewrites can be combined into a single pass over the table.

Scanning a large table to verify a new check constraint can take a long time, and other updates to the table are locked out until the `ALTER TABLE ADD CONSTRAINT` command is committed. The main purpose of the `NOT VALID` constraint option is to reduce the impact of adding a constraint on concurrent updates. With `NOT VALID`, the `ADD CONSTRAINT` command does not scan the table and can be committed immediately. After that, a `VALIDATE CONSTRAINT` command can be issued to verify that existing rows satisfy the constraint. The validation step does not need to lock out concurrent updates, since it knows that other transactions will be enforcing the constraint for rows that they insert or update; only pre-existing rows need to be checked. Hence, validation acquires only a `SHARE UPDATE EXCLUSIVE` lock on the table being altered. In addition to improving concurrency, it can be useful to use `NOT VALID` and `VALIDATE CONSTRAINT` in cases where the table is known to contain pre-existing violations. Once the constraint is in place, no new violations can be inserted, and you can correct the existing problems until `VALIDATE CONSTRAINT` finally succeeds.

The `DROP COLUMN` form does not physically remove the column, but simply makes it invisible to SQL operations. Subsequent insert and update operations in the table will store a null value for the column. Thus, dropping a column is quick but it will not immediately reduce the on-disk size of your table, as the space occupied by the dropped column is not reclaimed. The space will be reclaimed over time as existing rows are updated. If you drop the system `oid` column, however, the table is rewritten immediately.

To force immediate reclamation of space occupied by a dropped column, you can run one of the forms of `ALTER TABLE` that performs a rewrite of the whole table. This results in reconstructing each row with the dropped column replaced by a null value.

This table lists the `ALTER TABLE` operations that require a table rewrite when performed on tables defined with the specified type of table storage.

Operation (See Note)	Append-Optimized, Column-Oriented	Append-Optimized	Heap
`ALTER COLUMN TYPE`	No	Yes	Yes
`ADD COLUMN`	No	No	No
`ALTER COLUMN SET ENCODING`	No	N/A	N/A

> **Important** The forms of `ALTER TABLE` that perform a table rewrite are not MVCC-safe. After a table rewrite, the table will appear empty to concurrent transactions if they are using a snapshot taken before the rewrite occurred. See MVCC Caveats for more details.

Take special care when altering or dropping columns that are part of the WarehousePG distribution key as this can change the distribution policy for the table.

The `USING` option of `SET DATA TYPE` can actually specify any expression involving the old values of the row; that is, it can refer to other columns as well as the one being converted. This allows very general conversions to be done with the `SET DATA TYPE` syntax. Because of this flexibility, the `USING` expression is not applied to the column's default value (if any); the result might not be a constant expression as required for a default. This means that when there is no implicit or assignment cast from old to new type, `SET DATA TYPE` might fail to convert the default even though a `USING` clause is supplied. In such cases, drop the default with `DROP DEFAULT`, perform the `ALTER TYPE`, and then use `SET DEFAULT` to add a suitable new default. Similar considerations apply to indexes and constraints involving the column.

If a table has any descendant tables, it is not permitted to add, rename, or change the type of a column in the parent table without doing the same to the descendants. This ensures that the descendants always have columns matching the parent. Similarly, a `CHECK` constraint cannot be renamed in the parent without also renaming it in all descendants, so that `CHECK` constraints also match between the parent and its descendants. (That restriction does not apply to index-based constraints, however.) Also, because selecting from the parent also selects from its descendants, a constraint on the parent cannot be marked valid unless it is also marked valid for those descendants. In all of these cases, `ALTER TABLE ONLY` will be rejected.

A recursive `DROP COLUMN` operation will remove a descendant table's column only if the descendant does not inherit that column from any other parents and never had an independent definition of the column. A nonrecursive `DROP COLUMN` (`ALTER TABLE ONLY ... DROP COLUMN`) never removes any descendant columns, but instead marks them as independently defined rather than inherited. A nonrecursive `DROP COLUMN` command will fail for a partitioned table, because all partitions of a table must have the same columns as the partitioning root.

The actions for identity columns (`ADD GENERATED`, `SET` etc., `DROP IDENTITY`), as well as the actions `CLUSTER`, `OWNER`, and `TABLESPACE` never recurse to descendant tables; that is, they always act as though `ONLY` were specified. Adding a constraint recurses only for `CHECK` constraints that are not marked `NO INHERIT`.

WarehousePG does not currently support foreign key constraints. For a unique constraint to be enforced in WarehousePG, the table must be hash-distributed (not `DISTRIBUTED RANDOMLY`), and all of the distribution key columns must be the same as the initial columns of the unique constraint columns.

WarehousePG does not permit changing any part of a system catalog table.

Refer to CREATE TABLE for a further description of valid parameters.

Be aware of the following when altering partitioned tables using the *classic syntax*:

- The table name specified in the `ALTER TABLE` command must be the actual table name of the partition, not the partition alias that is specified in the classic syntax.
- Use the `pg_partition_tree()` function to view the structure of a partitioned table. This function returns the partition hierarchy, and can help you identify the particular partitions you may want to alter.
- These `ALTER PARTITION` operations are supported if no data is changed on a partitioned table that contains a leaf partition that has been exchanged to use an external table. Otherwise, an error is returned.
    - Adding or dropping a column.
    - Changing the data type of column.

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- These `ALTER PARTITION` operations are not supported for a partitioned table that contains a leaf partition that has been exchanged to use an external table:
    - Setting a sub-partition template.
    - Altering the partition properties.
    - Creating a default partition.
    - Setting a distribution policy.
    - Setting or dropping a `NOT NULL` constraint of column.
    - Adding or dropping constraints.
    - Splitting an external partition.

Examples

Add a column of type `varchar` to a table:

```
ALTER TABLE distributors ADD COLUMN address varchar(30);
```

To drop a column from a table:

```
ALTER TABLE distributors DROP COLUMN address RESTRICT;
```

To change the types of two existing columns in one operation:

```
ALTER TABLE distributors
    ALTER COLUMN address TYPE varchar(80),
    ALTER COLUMN name TYPE varchar(100);
```

To change an integer column containing Unix timestamps to `timestamp with time zone` via a `USING` clause:

```
ALTER TABLE foo
    ALTER COLUMN foo_timestamp SET DATA TYPE timestamp with time zone
    USING
        timestamp with time zone 'epoch' + foo_timestamp * interval '1 second';
```

The same, when the column has a default expression that won't automatically cast to the new data type:

```
ALTER TABLE foo
    ALTER COLUMN foo_timestamp DROP DEFAULT,
    ALTER COLUMN foo_timestamp TYPE timestamp with time zone
    USING
        timestamp with time zone 'epoch' + foo_timestamp * interval '1 second',
    ALTER COLUMN foo_timestamp SET DEFAULT now();
```

Rename an existing column:

```
ALTER TABLE distributors RENAME COLUMN address TO city;
```

Rename an existing table:

```
ALTER TABLE distributors RENAME TO suppliers;
```

To rename an existing constraint:

```
ALTER TABLE distributors RENAME CONSTRAINT zipchk TO zip_check;
```

Add a not-null constraint to a column:

```
ALTER TABLE distributors ALTER COLUMN street SET NOT NULL;
```

Rename an existing constraint:

```
ALTER TABLE distributors RENAME CONSTRAINT zipchk TO zip_check;
```

To remove a not-null constraint from a column:

```
ALTER TABLE distributors ALTER COLUMN street DROP NOT NULL;
```

Add a check constraint to a table and all of its children:

```
ALTER TABLE distributors ADD CONSTRAINT zipchk CHECK
  (char_length(zipcode) = 5);
```

To add a check constraint only to a table and not to its children:

```
ALTER TABLE distributors ADD CONSTRAINT zipchk CHECK (char_length(zipcode) = 5)
  NO INHERIT;
```

(The check constraint will not be inherited by future children, either.)

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Remove a check constraint from a table and all of its children:

```
ALTER TABLE distributors DROP CONSTRAINT zipchk;
```

Remove a check constraint from one table only:

```
ALTER TABLE ONLY distributors DROP CONSTRAINT zipchk;
```

(The check constraint remains in place for any child tables that inherit `distributors`.)

To add a (multicolumn) unique constraint to a table:

```
ALTER TABLE distributors ADD CONSTRAINT dist_id_zipcode_key UNIQUE (dist_id, zipcode);
```

To add an automatically named primary key constraint to a table, noting that a table can only ever have one primary key:

```
ALTER TABLE distributors ADD PRIMARY KEY (dist_id);
```

To move a table to a different tablespace:

```
ALTER TABLE distributors SET TABLESPACE fasttablespace;
```

Move a table to a different schema:

```
ALTER TABLE myschema.distributors SET SCHEMA yourschema;
```

Change a table's access method to `ao_row`:

```
ALTER TABLE distributors SET ACCESS METHOD ao_row;
```

Change a table's `blocksize` to `32768`:

```
ALTER TABLE distributors SET (blocksize = 32768);
```

Change a table's access method to `ao_row`, compression type to `zstd` and compression level to `4`:

```
ALTER TABLE sales SET ACCESS METHOD ao_row with (compresstype=zstd,compresslevel=4);
```

Alternatively, you can perform the same operation using `SET WITH`:

```
ALTER TABLE sales SET WITH (appendoptimized=true, compresstype=zstd, compresslevel=4);
```

Change access method for all existing partitions of a table:

```
ALTER TABLE sales SET ACCESS METHOD ao_row;
```

Change all future partitions of a table to have an access method of `heap`, leaving the access method of current partitions as is:

```
ALTER TABLE ONLY sales SET ACCESS METHOD heap;
```

Add a column and change the table's access method:

```
ALTER TABLE distributors SET ACCESS METHOD ao_row, ADD column j int;
```

Add a column and change table storage parameters:

```
ALTER TABLE distributors SET (compresslevel=7), ADD COLUMN k int;
```

Change the distribution policy of a table to replicated:

```
ALTER TABLE myschema.distributors SET DISTRIBUTED REPLICATED;
```

Change the distribution policy of a table to random and force a table rewrite:

```
ALTER TABLE distributors SET WITH (REORGANIZE=true) SET DISTRIBUTED RANDOMLY;
```

Set compression for a table and physically reorder the table by column `i`:

```
ALTER TABLE distributors
    REPACK BY COLUMNS (i),
    SET (compresstype=zstd, compresslevel=3);
```

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Modern Syntax Partioning Examples

Attach a partition to a range-partitioned table:

```
ALTER TABLE measurement
    ATTACH PARTITION measurement_y2016m07 FOR VALUES FROM ('2016-07-01') TO ('2016-08-01');
```

Attach a partition to a list-partitioned table:

```
ALTER TABLE cities
    ATTACH PARTITION cities_ab FOR VALUES IN ('a', 'b');
```

Attach a partition to a hash-partitioned table:

```
ALTER TABLE orders
    ATTACH PARTITION orders_p4 FOR VALUES WITH (MODULUS 4, REMAINDER 3);
```

Attach a default partition to a partitioned table:

```
ALTER TABLE cities
    ATTACH PARTITION cities_partdef DEFAULT;
```

Detach a partition from a partitioned table:

```
ALTER TABLE measurement
    DETACH PARTITION measurement_y2015m12;
```

Classic Syntax Partioning Examples

Add a new partition to a partitioned table:

```
ALTER TABLE sales ADD PARTITION
            START (date '2017-02-01') INCLUSIVE
            END (date '2017-03-01') EXCLUSIVE;
```

Add a default partition to an existing partition design:

```
ALTER TABLE sales ADD DEFAULT PARTITION other;
```

Rename a partition:

```
ALTER TABLE sales RENAME PARTITION FOR ('2016-01-01') TO
jan08;
```

Exchange a table into your partition design:

```
ALTER TABLE sales EXCHANGE PARTITION FOR ('2016-01-01') WITH
TABLE jan08;
```

Split the default partition (where the existing default partition's name is `other`) to add a new monthly partition for January 2017:

```
ALTER TABLE sales SPLIT DEFAULT PARTITION
  START ('2017-01-01') INCLUSIVE
  END ('2017-02-01') EXCLUSIVE
INTO (PARTITION jan09, PARTITION other);
```

Split a monthly partition into two with the first partition containing dates January 1-15 and the second partition containing dates January 16-31:

```
ALTER TABLE sales SPLIT PARTITION FOR ('2016-01-01')
AT ('2016-01-16')
INTO (PARTITION jan081to15, PARTITION jan0816to31);
```

For a multi-level partitioned table that consists of three levels, year, quarter, and region, exchange a leaf partition `region` with the table `region_new`.

```
ALTER TABLE sales ALTER PARTITION year_1 ALTER PARTITION quarter_4 EXCHANGE PARTITION region WITH TABLE region_new ;
```

In the previous command, the two `ALTER PARTITION` clauses identify which `region` partition to exchange. Both clauses are required to identify the specific partition to exchange.

Compatibility

The forms `ADD` (without `USING INDEX`), `DROP [COLUMN]`, `DROP IDENTITY`, `RESTART`, `SET DEFAULT`, `SET DATA TYPE` (without `USING`), `SET GENERATED`, and `SET <sequence_option>` conform with the SQL standard. The other forms are WarehousePG extensions of the SQL standard. Also, the ability to specify more than one manipulation in a single `ALTER TABLE` command is an extension.

`ALTER TABLE DROP COLUMN` can be used to drop the only column of a table, leaving a zero-column table. This is an extension of SQL, which disallows zero-column tables.

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See Also

CREATE TABLE, DROP TABLE

Parent topic: SQL Commands

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7.1.32 ALTER TABLESPACE

Changes the definition of a tablespace.

Synopsis

```
ALTER TABLESPACE <name> RENAME TO <new_name>

ALTER TABLESPACE <name> OWNER TO { <new_owner> | CURRENT_USER | SESSION_USER }

ALTER TABLESPACE <name> SET ( <tablespace_option> = <value> [, ... ] )

ALTER TABLESPACE <name> RESET ( <tablespace_option> [, ... ] )
```

Description

`ALTER TABLESPACE` changes the definition of a tablespace.

You must own the tablespace to use `ALTER TABLESPACE`. To alter the owner, you must also be a direct or indirect member of the new owning role. (Note that superusers have these privileges automatically.)

Parameters

name The name of an existing tablespace.

new*name The new name of the tablespace. The new name cannot begin with `pg* or* gp_ `*(reserved for system tablespaces).

new_owner The new owner of the tablespace.

tablespace_parameter A tablespace parameter to set or reset. Currently, the only available parameters are `seq_page_cost` and `random_page_cost`. Setting either value for a particular tablespace will override the planner's usual estimate of the cost of reading pages from tables in that tablespace, as established by the configuration parameters of the same name (see seq_page_cost, random_page_cost). This may be useful if one tablespace is located on a disk which is faster or slower than the remainder of the I/O subsystem.

Examples

Rename tablespace `index_space` to `fast_raid`:

```
ALTER TABLESPACE index_space RENAME TO fast_raid;
```

Change the owner of tablespace `index_space`:

```
ALTER TABLESPACE index_space OWNER TO mary;
```

Compatibility

There is no `ALTER TABLESPACE` statement in the SQL standard.

See Also

CREATE TABLESPACE, DROP TABLESPACE

Parent topic: SQL Commands

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7.1.33 ALTER TEXT SEARCH CONFIGURATION

Changes the definition of a text search configuration.

Synopsis

```
ALTER TEXT SEARCH CONFIGURATION <name>
    ADD MAPPING FOR <token_type> [, ... ] WITH <dictionary_name> [, ... ]
ALTER TEXT SEARCH CONFIGURATION <name>
    ALTER MAPPING FOR <token_type> [, ... ] WITH <dictionary_name> [, ... ]
ALTER TEXT SEARCH CONFIGURATION <name>
    ALTER MAPPING REPLACE <old_dictionary> WITH <new_dictionary>
ALTER TEXT SEARCH CONFIGURATION <name>
    ALTER MAPPING FOR <token_type> [, ... ] REPLACE <old_dictionary> WITH <new_dictionary>
ALTER TEXT SEARCH CONFIGURATION <name>
    DROP MAPPING [ IF EXISTS ] FOR <token_type> [, ... ]
ALTER TEXT SEARCH CONFIGURATION <name> RENAME TO <new_name>
ALTER TEXT SEARCH CONFIGURATION <name> OWNER TO { <new_owner> | CURRENT_USER | SESSION_USER }
ALTER TEXT SEARCH CONFIGURATION <name> SET SCHEMA <new_schema>
```

Description

`ALTER TEXT SEARCH CONFIGURATION` changes the definition of a text search configuration. You can modify its mappings from token types to dictionaries, or change the configuration's name or owner.

You must be the owner of the configuration to use `ALTER TEXT SEARCH CONFIGURATION`.

Parameters

name The name (optionally schema-qualified) of an existing text search configuration.

token_type The name of a token type that is emitted by the configuration's parser.

dictionary_name The name of a text search dictionary to be consulted for the specified token type(s). If multiple dictionaries are listed, they are consulted in the specified order.

old_dictionary The name of a text search dictionary to be replaced in the mapping.

new_dictionary The name of a text search dictionary to be substituted for old_dictionary.

new_name The new name of the text search configuration.

new_owner The new owner of the text search configuration.

new_schema The new schema for the text search configuration.

The `ADD MAPPING FOR` form installs a list of dictionaries to be consulted for the specified token type(s); it is an error if there is already a mapping for any of the token types. The `ALTER MAPPING FOR` form does the same, but first removing any existing mapping for those token types. The `ALTER MAPPING REPLACE` forms substitute new_dictionary for old_dictionary anywhere the latter appears. This is done for only the specified token types when `FOR` appears, or for all mappings of the configuration when it doesn't. The `DROP MAPPING` form removes all dictionaries for the specified token type(s), causing tokens of those types to be ignored by the text search configuration. It is an error if there is no mapping for the token types, unless `IF EXISTS` appears.

Examples

The following example replaces the `english` dictionary with the `swedish` dictionary anywhere that `english` is used within `my_config`.

```
ALTER TEXT SEARCH CONFIGURATION my_config
  ALTER MAPPING REPLACE english WITH swedish;
```

Compatibility

There is no `ALTER TEXT SEARCH CONFIGURATION` statement in the SQL standard.

See Also

CREATE TEXT SEARCH CONFIGURATION, DROP TEXT SEARCH CONFIGURATION

Parent topic: SQL Commands

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7.1.34 ALTER TEXT SEARCH DICTIONARY

Changes the definition of a text search dictionary.

Synopsis

```
ALTER TEXT SEARCH DICTIONARY <name> (
    <option> [ = <value> ] [, ... ]
)
ALTER TEXT SEARCH DICTIONARY <name> RENAME TO <new_name>
ALTER TEXT SEARCH DICTIONARY <name> OWNER TO { <new_owner> | CURRENT_USER | SESSION_USER }
ALTER TEXT SEARCH DICTIONARY <name> SET SCHEMA <new_schema>
```

Description

`ALTER TEXT SEARCH DICTIONARY` changes the definition of a text search dictionary. You can change the dictionary's template-specific options, or change the dictionary's name or owner.

You must be the owner of the dictionary to use `ALTER TEXT SEARCH DICTIONARY`.

Parameters

name The name (optionally schema-qualified) of an existing text search dictionary.

option The name of a template-specific option to be set for this dictionary.

value The new value to use for a template-specific option. If the equal sign and value are omitted, then any previous setting for the option is removed from the dictionary, allowing the default to be used.

new_name The new name of the text search dictionary.

new_owner The new owner of the text search dictionary.

new_schema The new schema for the text search dictionary.

Template-specific options can appear in any order.

Examples

The following example command changes the stop word list for a Snowball-based dictionary. Other parameters remain unchanged.

```
ALTER TEXT SEARCH DICTIONARY my_dict ( StopWords = newrussian );
```

The following example command changes the language option to `dutch`, and removes the stop word option entirely:

```
ALTER TEXT SEARCH DICTIONARY my_dict ( language = dutch, StopWords );
```

The following example command "updates" the dictionary's definition without actually changing anything:

```
ALTER TEXT SEARCH DICTIONARY my_dict ( dummy );
```

(The reason this works is that the option removal code doesn't complain if there is no such option.) This trick is useful when changing configuration files for the dictionary: the `ALTER` will force existing database sessions to re-read the configuration files, which they would otherwise never do if they had read them earlier.

Compatibility

There is no `ALTER TEXT SEARCH DICTIONARY` statement in the SQL standard.

See Also

CREATE TEXT SEARCH DICTIONARY, DROP TEXT SEARCH DICTIONARY

Parent topic: SQL Commands

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7.1.35 ALTER TEXT SEARCH PARSER

Changes the definition of a text search parser.

Synopsis

```
ALTER TEXT SEARCH PARSER <name> RENAME TO <new_name>
ALTER TEXT SEARCH PARSER <name> SET SCHEMA <new_schema>
```

Description

`ALTER TEXT SEARCH PARSER` changes the definition of a text search parser. Currently, the only supported functionality is to change the parser's name.

You must be a superuser to use `ALTER TEXT SEARCH PARSER`.

Parameters

name The name (optionally schema-qualified) of an existing text search parser.

new_name The new name of the text search parser.

new_schema The new schema for the text search parser.

Compatibility

There is no `ALTER TEXT SEARCH PARSER` statement in the SQL standard.

See Also

CREATE TEXT SEARCH PARSER, DROP TEXT SEARCH PARSER

Parent topic: SQL Commands

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7.1.36 ALTER TEXT SEARCH TEMPLATE

Changes the definition of a text search template.

Synopsis

```
ALTER TEXT SEARCH TEMPLATE <name> RENAME TO <new_name>
ALTER TEXT SEARCH TEMPLATE <name> SET SCHEMA <new_schema>
```

Description

`ALTER TEXT SEARCH TEMPLATE` changes the definition of a text search parser. Currently, the only supported functionality is to change the template's name.

You must be a superuser to use `ALTER TEXT SEARCH TEMPLATE`.

Parameters

name The name (optionally schema-qualified) of an existing text search template.

new_name The new name of the text search template.

new_schema The new schema for the text search template.

Compatibility

There is no `ALTER TEXT SEARCH TEMPLATE` statement in the SQL standard.

See Also

CREATE TEXT SEARCH TEMPLATE, DROP TEXT SEARCH TEMPLATE

Parent topic: SQL Commands

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7.1.37 ALTER TYPE

Changes the definition of a data type.

Synopsis

```
ALTER TYPE <name> <action> [, ... ]
ALTER TYPE <name> OWNER TO { <new_owner> | CURRENT_USER | SESSION_USER }
ALTER TYPE <name> RENAME ATTRIBUTE <attribute_name> TO <new_attribute_name> [ CASCADE | RESTRICT ]
ALTER TYPE <name> RENAME TO <new_name>
ALTER TYPE <name> SET SCHEMA <new_schema>
ALTER TYPE <name> ADD VALUE [ IF NOT EXISTS ] <new_enum_value> [ { BEFORE | AFTER } <neighbor_enum_value> ]
ALTER TYPE <name> RENAME VALUE <existing_enum_value> to <new_enum_value>
ALTER TYPE <name> SET DEFAULT ENCODING ( <storage_directive> )

where <action> is one of:

  ADD ATTRIBUTE <attribute_name> <data_type> [ COLLATE <collation> ] [ CASCADE | RESTRICT ]
  DROP ATTRIBUTE [ IF EXISTS ] <attribute_name> [ CASCADE | RESTRICT ]
  ALTER ATTRIBUTE <attribute_name> [ SET DATA ] TYPE <data_type> [ COLLATE <collation> ] [ CASCADE | RESTRICT ]

where <storage_directive> is:

   COMPRESSTYPE={ZLIB | ZSTD | RLE_TYPE | NONE}
   COMPRESSLEVEL={0-19}
   BLOCKSIZE={8192-2097152}
```

Description

`ALTER TYPE` changes the definition of an existing type. There are several subforms:

`ADD ATTRIBUTE` Adds a new attribute to a composite type, using the same syntax as CREATE TYPE.

`DROP ATTRIBUTE [ IF EXISTS ]` Drops an attribute from a composite type. If `IF EXISTS` is specified and the attribute does not exist, no error is thrown. In this case WarehousePG issues a notice instead.

`SET DATA TYPE` Changes the type of an attribute of a composite type.

`OWNER` Changes the owner of the type.

`RENAME` Changes the name of the type or the name of an individual attribute of a composite type.

`SET SCHEMA` Moves the type into another schema.

`ADD VALUE [ IF NOT EXISTS ] [ BEFORE | AFTER ]` Adds a new value to an enum type. The new value's place in the enum's ordering can be specified as being `BEFORE` or `AFTER` one of the existing values. Otherwise, the new item is added at the end of the list of values.

If `IF NOT EXISTS` is specified, it is not an error if the type already contains the new value; WarehousePG issues a notice but takes no other action. Otherwise, an error will occur if the new value is already present.

`RENAME VALUE` Renames a value of an enum type. The value's place in the enum's ordering is not affected. An error will occur if the specified value is not present or the new name is already present.

The `ADD ATTRIBUTE`, `DROP ATTRIBUTE`, and `ALTER ATTRIBUTE` actions can be combined into a list of multiple alterations to apply in parallel. For example, it is possible to add several attributes and/or alter the type of several attributes in a single command.

You can change the name, the owner, and the schema of a type. You can also add or update storage options for a scalar type.

> **Note** WarehousePG does not support adding storage options for row or composite types.

You must own the type to use `ALTER TYPE`. To change the schema of a type, you must also have `CREATE` privilege on the new schema. To alter the owner, you must also be a direct or indirect member of the new owning role, and that role must have `CREATE` privilege on the type's schema. (These restrictions enforce that altering the owner does not do anything that could be done by dropping and recreating the type. However, a superuser can alter ownership of any type.) To add an attribute or alter an attribute type, you must also have `USAGE` privilege on the data type.

Parameters

name The name (optionally schema-qualified) of an existing type to alter.

new_name The new name for the type.

new_owner The user name of the new owner of the type.

new_schema The new schema for the type.

attribute_name The name of the attribute to add, alter, or drop.

new_attribute_name The new name of the attribute to be renamed.

data_type The data type of the attribute to add, or the new type of the attribute to alter.

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new_enum_value The new value to be added to an enum type's list of values. Like all enum literals, it must be quoted.

neighbor_enum_value The existing enum value that the new value should be added immediately before or after in the enum type's sort ordering. Like all enum literals, it must be quoted.

existing_enum_value The existing enum value that should be renamed. Like all enum literals, it must be quoted.

CASCADE Automatically propagate the operation to typed tables of the type being altered, and their descendants.

RESTRICT Refuse the operation if the type being altered is the type of a typed table. This is the default.

storage_directive Identifies default storage options for the type when specified in a table column definition. Options include `COMPRESSTYPE`, `COMPRESSLEVEL`, and `BLOCKSIZE`.

COMPRESSTYPE — Set to `ZLIB` (the default), `ZSTD` or `RLE_TYPE` to specify the type of compression used.

COMPRESSLEVEL — For Zstd compression, set to an integer value from 1 (fastest compression) to 19 (highest compression ratio). For zlib compression, the valid range is from 1 to 9. For `RLE_TYPE`, the compression level can be set to an integer value from 1 (fastest compression) to 6 (highest compression ratio). The default compression level is 1.

BLOCKSIZE — Set to the size, in bytes, for each block in the column. The `BLOCKSIZE` must be between 8192 and 2097152 bytes, and be a multiple of 8192. The default block size is 32768.

```
> **Note** storage\_directives defined at the table- or column-level override the default storage options defined for a type.
```

Notes

If `ALTER TYPE ... ADD VALUE` (the form that adds a new value to an enum type) is executed inside a transaction block, the new value cannot be used until after the transaction has been committed.

Comparisons involving an added enum value will sometimes be slower than comparisons involving only original members of the enum type. This will usually only occur if `BEFORE` or `AFTER` is used to set the new value's sort position somewhere other than at the end of the list. However, sometimes it will happen even though the new value is added at the end (this occurs if the OID counter "wrapped around" since the original creation of the enum type). The slowdown is usually insignificant; but if it matters, optimal performance can be regained by dropping and recreating the enum type, or by dumping and reloading the database.

Examples

To rename the data type named `electronic_mail`:

```
ALTER TYPE electronic_mail RENAME TO email;
```

To change the owner of the user-defined type `email` to `joe`:

```
ALTER TYPE email OWNER TO joe;
```

To change the schema of the user-defined type `email` to `customers`:

```
ALTER TYPE email SET SCHEMA customers;
```

To set or alter the compression type and compression level of the user-defined type named `int33`:

```
ALTER TYPE int33 SET DEFAULT ENCODING (compresstype=zlib, compresslevel=7);
```

To add a new attribute to a type:

```
ALTER TYPE compfoo ADD ATTRIBUTE f3 int;
```

To add a new value to an enum type in a particular sort position:

```
ALTER TYPE colors ADD VALUE 'orange' AFTER 'red';
```

To rename an enum value:

```
ALTER TYPE colors RENAME VALUE 'purple' TO 'mauve';
```

Compatibility

The variants to add and drop attributes are part of the SQL standard; the other variants are WarehousePG extensions.

See Also

CREATE TYPE, DROP TYPE

Parent topic: SQL Commands

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7.1.38 ALTER USER

Changes the definition of a database role.

Synopsis

```
ALTER USER <role_specification> [WITH] <option> [ ... ]

where option can be:

      SUPERUSER | NOSUPERUSER
    | CREATEDB | NOCREATEDB
    | CREATEROLE | NOCREATEROLE
    | CREATEEXTTABLE | NOCREATEEXTTABLE
      [ ( <attribute>='<value>'[, ...] ) ]
           where <attributes> and <value> are:
           type='readable'|'writable'
           protocol='gpfdist'|'http'
    | INHERIT | NOINHERIT
    | LOGIN | NOLOGIN
    | REPLICATION | NOREPLICATION
    | BYPASSRLS | NOBYPASSRLS
    | CONNECTION LIMIT <connlimit>
    | [ENCRYPTED ] PASSWORD '<password>' | PASSWORD NULL
    | VALID UNTIL '<timestamp>'
    | [ DENY <deny_point> ]
    | [ DENY BETWEEN <deny_point> AND <deny_point>]
    | [ DROP DENY FOR <deny_point> ]

ALTER USER <name> RENAME TO <new_name>

ALTER USER <name> RESOURCE QUEUE {<queue_name> | NONE}

ALTER USER <name> RESOURCE GROUP {<group_name> | NONE}

ALTER USER { <role_specification> | ALL } [ IN DATABASE <database_name> ] SET <configuration_parameter> {TO | =} {<value> | DEFAULT}
ALTER USER { <role_specification> | ALL } [ IN DATABASE <database_name> ] SET <configuration_parameter> FROM CURRENT
ALTER USER { <role_specification> | ALL } [ IN DATABASE <database_name> ] RESET <configuration_parameter>
ALTER USER { <role_specification> | ALL } [ IN DATABASE <database_name> ] RESET ALL

where <role_specification> can be:

    role_name
  | CURRENT_USER
  | SESSION_USER
```

Description

`ALTER USER` is an alias for ALTER ROLE.

Compatibility

The `ALTER USER` statement is a WarehousePG extension. The SQL standard leaves the definition of users to the implementation.

See Also

ALTER ROLE

Parent topic: SQL Commands

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7.1.39 ALTER USER MAPPING

Changes the definition of a user mapping for a foreign server.

Synopsis

```
ALTER USER MAPPING FOR { <user_name> | USER | CURRENT_USER | SESSION_USER | PUBLIC }
    SERVER <server_name>
    OPTIONS ( [ ADD | SET | DROP ] <option> ['<value>'] [, ... ] )
```

Description

`ALTER USER MAPPING` changes the definition of a user mapping for a foreign server.

The owner of a foreign server can alter user mappings for that server for any user. Also, a user granted `USAGE` privilege on the server can alter a user mapping for their own user name.

Parameters

user_name User name of the mapping. `CURRENT_USER` and `USER` match the name of the current user. `PUBLIC` is used to match all present and future user names in the system.

server_name Server name of the user mapping.

OPTIONS ([ADD | SET | DROP] option ['value'] [, ...]) Change options for the user mapping. The new options override any previously specified options `ADD`, `SET`, and `DROP` specify the action to perform. If no operation is explicitly specified, the default operation is `ADD`. Option names must be unique. WarehousePG validates names and values using the server's foreign-data wrapper.

Examples

Change the password for user mapping `bob`, server `foo`:

```
ALTER USER MAPPING FOR bob SERVER foo OPTIONS (SET password 'public');
```

Compatibility

`ALTER USER MAPPING` conforms to ISO/IEC 9075-9 (SQL/MED). There is a subtle syntax issue: The standard omits the `FOR` key word. Since both `CREATE USER MAPPING` and `DROP USER MAPPING` use `FOR` in analogous positions, WarehousePG diverges from the standard here in the interest of consistency and interoperability.

See Also

CREATE USER MAPPING, DROP USER MAPPING

Parent topic: SQL Commands

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7.1.40 ALTER VIEW

Changes properties of a view.

Synopsis

```
ALTER VIEW [ IF EXISTS ] <name> ALTER [ COLUMN ] <column_name> SET DEFAULT <expression>

ALTER VIEW [ IF EXISTS ] <name> ALTER [ COLUMN ] <column_name> DROP DEFAULT

ALTER VIEW [ IF EXISTS ] <name> OWNER TO { <new_owner> | CURRENT_USER | SESSION_USER }

ALTER VIEW [ IF EXISTS ] <name> RENAME TO <new_name>

ALTER VIEW [ IF EXISTS ] <name> SET SCHEMA <new_schema>

ALTER VIEW [ IF EXISTS ] <name> SET ( <view_option_name> [= <view_option_value>] [, ... ] )

ALTER VIEW [ IF EXISTS ] <name> RESET ( <view_option_name> [, ... ] )
```

Description

`ALTER VIEW` changes various auxiliary properties of a view. (If you want to modify the view's defining query, use `CREATE OR REPLACE VIEW`).

You must own the view to use `ALTER VIEW`. To change a view's schema you must also have `CREATE` privilege on the new schema. To alter the owner, you must also be a direct or indirect member of the new owning role, and that role must have `CREATE` privilege on the view's schema. These restrictions enforce that altering the owner does not do anything you could not do by dropping and recreating the view. However, a superuser can alter ownership of any view.

Parameters

name The name (optionally schema-qualified) of an existing view.

IF EXISTS Do not throw an error if the view does not exist. WarehousePG issues a notice in this case.

SET/DROP DEFAULT These forms set or remove the default value for a column. A view column's default value is substituted into any `INSERT` or `UPDATE` command whose target is the view, before applying any rules or triggers for the view. The view's default will therefore take precedence over any default values from underlying relations.

new_owner The user name of the new owner of the view.

new_name The new name of the view.

new_schema The new schema for the view.

SET (view_option_name [= view_option_value][, ...]) RESET (view_option_name [, ...]) Sets or resets a view option. Currently supported options are:

```
check\_option \(string\)
Changes the check option of the view. The value must be `local` or `cascaded`.

security\_barrier \(boolean\)
Changes the security-barrier property of the view. The value must be a Boolean value, such as `true` or `false`.
```

Notes

For historical reasons, `ALTER TABLE` can be used with views, too; however, the only variants of `ALTER TABLE` that are allowed with views are equivalent to the statements shown above.

Examples

To rename the view `foo` to `bar`:

```
ALTER VIEW foo RENAME TO bar;
```

To attach a default column value to an updatable view:

```
CREATE TABLE base_table (id int, ts timestamptz);
CREATE VIEW a_view AS SELECT * FROM base_table;
ALTER VIEW a_view ALTER COLUMN ts SET DEFAULT now();
INSERT INTO base_table(id) VALUES(1);  -- ts will receive a NULL
INSERT INTO a_view(id) VALUES(2);  -- ts will receive the current time
```

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Compatibility

`ALTER VIEW` is a WarehousePG extension of the SQL standard.

See Also

CREATE VIEW, DROP VIEW

Parent topic: SQL Commands

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7.1.41 ANALYZE

Collects statistics about a database.

Synopsis

```
ANALYZE [VERBOSE] [SKIP_LOCKED] [<table> [ (<column> [, ...] ) ]]

ANALYZE [VERBOSE] [SKIP_LOCKED] {<root_partition_table_name>|<leaf_partition_table_name>} [ (<column> [, ...] )]

ANALYZE [VERBOSE] [SKIP_LOCKED] ROOTPARTITION {ALL | <root_partition_table_name> [ (<column> [, ...] )]}
```

Description

`ANALYZE` collects statistics about the contents of tables in the database, and stores the results in the system table*pg_statistic*. Subsequently, WarehousePG uses these statistics to help determine the most efficient execution plans for queries. For information about the table statistics that are collected, see Notes.

With no parameter, `ANALYZE` collects statistics for every table in the current database. You can specify a table name to collect statistics for a single table. You can specify a set of column names in a specific table, in which case the statistics only for those columns from that table are collected.

`ANALYZE` does not collect statistics on external tables.

For partitioned tables, `ANALYZE` collects additional statistics, HyperLogLog (HLL) statistics, on the leaf partitions. HLL statistics are used are used to derive number of distinct values (NDV) for queries against partitioned tables.

- When aggregating NDV estimates across multiple leaf partitions, HLL statistics generate a more accurate NDV estimates than the standard table statistics.
- When updating HLL statistics, `ANALYZE` operations are required only on leaf partitions that have changed. For example, `ANALYZE` is required if the leaf partition data has changed, or if the leaf partition has been exchanged with another table. For more information about updating partitioned table statistics, see Notes.

> **Important** If you intend to run queries on partitioned tables with GPORCA enabled (the default), then you must collect statistics on the root partition of the partitioned table with the `ANALYZE` or `ANALYZE ROOTPARTITION` command. For information about collecting statistics on partitioned tables and when the `ROOTPARTITION` keyword is required, see Notes. For information about GPORCA, see Overview of GPORCA in the *WarehousePG Administrator Guide*.

> **Note** You can also use the WarehousePG utility `analyzedb` to update table statistics. The `analyzedb` utility can update statistics for multiple tables concurrently. The utility can also check table statistics and update statistics only if the statistics are not current or do not exist. For information about the utility, see the *WarehousePG Utility Guide*.

Parameters

{ root_partition_table_name | leaf_partition_table_name } [(column [, ...])] Collect statistics for partitioned tables including HLL statistics. HLL statistics are collected only on leaf partitions.

`ANALYZE root\_partition\_table\_name` , collects statistics on all leaf partitions and the root partition.

`ANALYZE leaf\_partition\_table\_name` , collects statistics on the leaf partition.

By default, if you specify a leaf partition, and all other leaf partitions have statistics, `ANALYZE` updates the root partition statistics. If not all leaf partitions have statistics, `ANALYZE` logs information about the leaf partitions that do not have statistics. For information about when root partition statistics are collected, see Notes.

ROOTPARTITION [ALL] Collect statistics only on the root partition of partitioned tables based on the data in the partitioned table. If possible, `ANALYZE` uses leaf partition statistics to generate root partition statistics. Otherwise, `ANALYZE` collects the statistics by sampling leaf partition data. Statistics are not collected on the leaf partitions, the data is only sampled. HLL statistics are not collected.

For information about when the `ROOTPARTITION` keyword is required, see Notes.

When you specify `ROOTPARTITION` , you must specify either `ALL` or the name of a partitioned table.

If you specify `ALL` with `ROOTPARTITION` , WarehousePG collects statistics for the root partition of all partitioned tables in the database. If there are no partitioned tables in the database, a message stating that there are no partitioned tables is returned. For tables that are not partitioned tables, statistics are not collected.

If you specify a table name with `ROOTPARTITION` and the table is not a partitioned table, no statistics are collected for the table and a warning message is returned.

The `ROOTPARTITION` clause is not valid with `VACUUM ANALYZE` . The command `VACUUM ANALYZE ROOTPARTITION` returns an error.

If all the leaf partitions have statistics, performing `ANALYZE ROOTPARTITION` to generate root partition statistics should be quick (a few seconds depending on the number of partitions and table columns). If some of the leaf partitions do not have statistics, then all the table data is sampled to generate root partition statistics. Sampling table data takes longer and results in lower quality root partition statistics.

For the partitioned table *sales_curr_yr*, this example command collects statistics only on the root partition of the partitioned table. `ANALYZE ROOTPARTITION sales_curr_yr;`

This example `ANALYZE` command collects statistics on the root partition of all the partitioned tables in the database.

```
ANALYZE ROOTPARTITION ALL;
```

VERBOSE Enables display of progress messages. When specified, `ANALYZE` emits this information

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```
-   The table that is being processed.
-   The query that is run to generate the sample table.
-   The column for which statistics is being computed.
-   The queries that are issued to collect the different statistics for a single column.
-   The statistics that are collected.
```

SKIP_LOCKED Specifies that `ANALYZE` should not wait for any conflicting locks to be released when beginning work on a relation: if it cannot lock a relation immediately without waiting, it skips the relation. Note that even with this option, `ANALYZE` may still block when opening the relation's indexes or when acquiring sample rows from partitions, table inheritance children, and some types of foreign tables. Also, while `ANALYZE` ordinarily processes all partitions of specified partitioned tables, this option will cause `ANALYZE` to skip all partitions if there is a conflicting lock on the partitioned table.

table The name (possibly schema-qualified) of a specific table to analyze. If omitted, all regular tables (but not foreign tables) in the current database are analyzed.

column The name of a specific column to analyze. Defaults to all columns.

Notes

Foreign tables are analyzed only when explicitly selected. Not all foreign data wrappers support `ANALYZE`. If the table's wrapper does not support `ANALYZE`, the command prints a warning and does nothing.

It is a good idea to run `ANALYZE` periodically, or just after making major changes in the contents of a table. Accurate statistics helps WarehousePG choose the most appropriate query plan, and thereby improve the speed of query processing. A common strategy for read-mostly databases is to run VACUUM and `ANALYZE` once a day during a low-usage time of day. (This will not be sufficient if there is heavy update activity.) You can check for tables with missing statistics using the `gp_stats_missing` view, which is in the `gp_toolkit` schema:

```
SELECT * from gp_toolkit.gp_stats_missing;
```

`ANALYZE` requires `SHARE UPDATE EXCLUSIVE` lock on the target table. This lock conflicts with these locks: `SHARE UPDATE EXCLUSIVE`, `SHARE`, `SHARE ROW EXCLUSIVE`, `EXCLUSIVE`, `ACCESS EXCLUSIVE`.

If you run `ANALYZE` on a table that does not contain data, statistics are not collected for the table. For example, if you perform a `TRUNCATE` operation on a table that has statistics, and then run `ANALYZE` on the table, the statistics do not change.

For a partitioned table, specifying which portion of the table to analyze, the root partition or sub-partitions (leaf partitions) can be useful if the partitioned table has a large number of partitions that have been analyzed and only a few leaf partitions have changed.

> **Note** When you create a partitioned table with the `CREATE TABLE` command, WarehousePG creates the table that you specify (the root partition or parent table), and also creates a hierarchy of tables based on the partition hierarchy that you specified (the child tables).

- When you run `ANALYZE` on the root partitioned table, statistics are collected for all the leaf partitions. Leaf partitions are the lowest-level tables in the hierarchy of child tables created by WarehousePG for use by the partitioned table.
- When you run `ANALYZE` on a leaf partition, statistics are collected only for that leaf partition and the root partition. If data in the leaf partition has changed (for example, you made significant updates to the leaf partition data or you exchanged the leaf partition), then you can run ANALYZE on the leaf partition to collect table statistics. By default, if all other leaf partitions have statistics, the command updates the root partition statistics.

  For example, if you collected statistics on a partitioned table with a large number partitions and then updated data in only a few leaf partitions, you can run `ANALYZE` only on those partitions to update statistics on the partitions and the statistics on the root partition.
- When you run `ANALYZE` on a child table that is not a leaf partition, statistics are not collected.

  For example, you can create a partitioned table with partitions for the years 2006 to 2016 and sub-partitions for each month in each year. If you run `ANALYZE` on the child table for the year 2013 no statistics are collected. If you run `ANALYZE` on the leaf partition for March of 2013, statistics are collected only for that leaf partition.

For a partitioned table that contains a leaf partition that has been exchanged to use an external table, `ANALYZE` does not collect statistics for the external table partition:

- If `ANALYZE` is run on an external table partition, the partition is not analyzed.
- If `ANALYZE` or `ANALYZE ROOTPARTITION` is run on the root partition, external table partitions are not sampled and root table statistics do not include external table partition.
- If the `VERBOSE` clause is specified, an informational message is displayed: `skipping external table`.

The WarehousePG server configuration parameter optimizer_analyze_root_partition determines when statistics are collected on a root partitioned table. If the parameter is `on` (the default), the `ROOTPARTITION` keyword is not required to collect statistics on the root partition when you run `ANALYZE`. Root partition statistics are collected when you run `ANALYZE` on the root partition, or when you run `ANALYZE` on a leaf partition of the partitioned table and the other leaf partitions have statistics. If the parameter is `off`, you must run `ANALZYE ROOTPARTITION` to collect root partition statistics.

The statistics collected by `ANALYZE` usually include a list of some of the most common values in each column and a histogram showing the approximate data distribution in each column. One or both of these may be omitted if `ANALYZE` deems them uninteresting (for example, in a unique-key column, there are no common values) or if the column data type does not support the appropriate operators.

For large tables, `ANALYZE` takes a random sample of the table contents, rather than examining every row. This allows even very large tables to be analyzed in a small amount of time. Note, however, that the statistics are only approximate, and will change slightly each time `ANALYZE` is run, even if the actual table contents did not change. This may result in small changes in the planner's estimated costs shown by `EXPLAIN`. In rare situations, this non-determinism will cause the query optimizer to choose a different query plan between runs of `ANALYZE`. To avoid this, raise the amount of statistics collected by `ANALYZE` by adjusting the default_statistics_target configuration parameter, or on a column-by-column basis by setting the per-column statistics target with `ALTER TABLE ... ALTER COLUMN ... SET (n_distinct ...)` (see `ALTER TABLE`). The target value sets the maximum number of entries in the most-common-value list and the maximum number of bins in the histogram. The default target value is 100, but this can be adjusted up or down to trade off accuracy of planner estimates against the time taken for `ANALYZE` and the amount of space occupied in `pg_statistic`. In particular, setting the statistics target to zero deactivates collection of statistics for that column. It may be useful to do that for columns that are never used as part of the `WHERE`, `GROUP BY`, or `ORDER BY` clauses of queries, since the planner will have no use for statistics on such columns.

The largest statistics target among the columns being analyzed determines the number of table rows sampled to prepare the statistics. Increasing the target causes a proportional increase in the time and space needed to do `ANALYZE`.

One of the values estimated by `ANALYZE` is the number of distinct values that appear in each column. Because only a subset of the rows are examined, this estimate can sometimes be quite inaccurate, even with the largest possible statistics target. If this inaccuracy leads to bad query plans, a more accurate value can be determined manually and then installed with `ALTER TABLE ... ALTER COLUMN ... SET STATISTICS DISTINCT` (see ALTER TABLE).

When WarehousePG performs an `ANALYZE` operation to collect statistics for a table and detects that all the sampled table data pages are empty (do not contain valid data), WarehousePG displays a message that a `VACUUM FULL` operation should be performed. If the sampled pages are empty, the table statistics will be inaccurate. Pages become empty after a large number of changes to the table, for example deleting a large number of rows. A `VACUUM FULL` operation removes the empty pages and allows an `ANALYZE` operation to collect accurate statistics.

If there are no statistics for the table, the server configuration parameter gp_enable_relsize_collection controls whether the Postgres-based planner uses a default statistics file or estimates the size of a table using the `pg_relation_size` function. By default, the Postgres-based planner uses the default statistics file to estimate the number of rows if statistics are not available.

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Examples

Collect statistics for the table `mytable`:

```
ANALYZE mytable;
```

Compatibility

There is no `ANALYZE` statement in the SQL standard.

See Also

ALTER TABLE, EXPLAIN, VACUUM, analyzedb.

Parent topic: SQL Commands

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7.1.42 BEGIN

Starts a transaction block.

Synopsis

```
BEGIN [WORK | TRANSACTION] [<transaction_mode>]

where <transaction_mode> is:

   ISOLATION LEVEL {READ UNCOMMITTED | READ COMMITTED | REPEATABLE READ | SERIALIZABLE}
   READ WRITE | READ ONLY
   [NOT] DEFERRABLE
```

Description

`BEGIN` initiates a transaction block, that is, all statements after a `BEGIN` command will be run in a single transaction until an explicit COMMIT or ROLLBACK is given. By default (without `BEGIN`), WarehousePG runs transactions in "autocommit" mode, that is, each statement is run in its own transaction and a commit is implicitly performed at the end of the statement (if execution was successful, otherwise a rollback is done).

Statements are run more quickly in a transaction block, because transaction start/commit requires significant CPU and disk activity. Execution of multiple statements inside a transaction is also useful to ensure consistency when making several related changes: other sessions will be unable to see the intermediate states wherein not all the related updates have been done.

If the isolation level, read/write mode, or deferrable mode is specified, the new transaction has those characteristics, as if SET TRANSACTION was run.

Parameters

WORK TRANSACTION Optional key words. They have no effect.

Refer to SET TRANSACTION for information on the meaning of the other parameters to this statement.

Notes

START TRANSACTION has the same functionality as `BEGIN`.

Use COMMIT or ROLLBACK to terminate a transaction block.

Issuing `BEGIN` when already inside a transaction block will provoke a warning message. The state of the transaction is not affected. To nest transactions within a transaction block, use savepoints (seeSAVEPOINT).

For reasons of backwards compatibility, the commas between successive transaction_modes can be omitted.

Examples

To begin a transaction block:

```
BEGIN;
```

Compatibility

`BEGIN` is a WarehousePG language extension. It is equivalent to the SQL-standard command START TRANSACTION, whose reference page contains additional compatibility information.

The `DEFERRABLE` transaction_mode is a WarehousePG language extension.

Incidentally, the `BEGIN` key word is used for a different purpose in embedded SQL. You are advised to be careful about the transaction semantics when porting database applications.

See Also

COMMIT, ROLLBACK, SAVEPOINT, START TRANSACTION

Parent topic: SQL Commands

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7.1.43 CALL

Invokes a procedure.

Synopsis

```
CALL <name> ( [ <argument> ] [, ...] )
```

Description

`CALL` executes a procedure.

If the procedure has any output parameters, then a result row will be returned, containing the values of those parameters.

Parameters

name The name (optionally schema-qualified) of the procedure.

argument An input argument for the procedure call.

Notes

The user must have `EXECUTE` privilege on the procedure in order to be allowed to invoke it.

To call a function (not a procedure), use SELECT instead.

If `CALL` is invoked in a transaction block, then the called procedure cannot run transaction control statements. Transaction control statements are only allowed if `CALL` is invoked in its own transaction.

PL/pgSQL handles output parameters in `CALL` commands differently; refer to Calling a Procedure in the PostgreSQL documentation for more information.

Examples

```
CALL do_db_maintenance();
```

Compatibility

`CALL` conforms to the SQL standard.

See Also

CREATE PROCEDURE

Parent topic: SQL Commands

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7.1.44 CHECKPOINT

Forces a write-ahead log checkpoint.

Synopsis

```
CHECKPOINT
```

Description

A checkpoint is a point in the write-ahead log sequence at which all data files have been updated to reflect the information in the log. All data files will be flushed to disk.

The `CHECKPOINT` command forces an immediate checkpoint when the command is issued, without waiting for a regular checkpoint scheduled by the system. `CHECKPOINT` is not intended for use during normal operation.

If run during recovery, the `CHECKPOINT` command will force a restartpoint rather than writing a new checkpoint.

Only superusers may call `CHECKPOINT`.

Compatibility

The `CHECKPOINT` command is a WarehousePG extension.

Parent topic: SQL Commands

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7.1.45 CLOSE

Closes a cursor.

Synopsis

```
CLOSE { <cursor_name> | ALL }
```

Description

`CLOSE` frees the resources associated with an open cursor. After the cursor is closed, no subsequent operations are allowed on it. A cursor should be closed when it is no longer needed.

Every non-holdable open cursor is implicitly closed when a transaction is terminated by `COMMIT` or `ROLLBACK`. A holdable cursor is implicitly closed if the transaction that created it is prematurely ended via `ROLLBACK`. If the creating transaction successfully commits, the holdable cursor remains open until an explicit `CLOSE` is run, or the client disconnects.

Parameters

cursor_name The name of an open cursor to close.

ALL Close all open cursors.

Notes

WarehousePG does not have an explicit `OPEN` cursor statement. A cursor is considered open when it is declared. Use theDECLARE statement to declare (and open) a cursor.

You can see all available cursors by querying the pg_cursors system view.

If a cursor is closed after a savepoint which is later rolled back, the `CLOSE` is not rolled back; that is, the cursor remains closed.

Examples

Close the cursor `portala`:

```
CLOSE portala;
```

Compatibility

`CLOSE` is fully conforming with the SQL standard. `CLOSE ALL` is a WarehousePG extension.

See Also

DECLARE, FETCH, MOVE, RETRIEVE

Parent topic: SQL Commands

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7.1.46 CLUSTER

Physically reorders a table on disk according to an index.

Synopsis

```
CLUSTER <indexname> ON <table_name>

CLUSTER [VERBOSE] <table_name> [ USING <index_name> ]

CLUSTER [VERBOSE]
```

Description

`CLUSTER` instructs WarehousePG to order the table specified by `<table_name>` based on the index specified by `<index_name>`. The index must already have been defined on `<table_name>`.

WarehousePG supports `CLUSTER` operations on append-optimized tables only for B-tree indexes.

> **Note** WarehousePG 7 does not support `CLUSTER`ing a partitioned table.

When a table is clustered, it is physically reordered on disk based on the index information. Clustering is a one-time operation: when the table is subsequently updated, the changes are not clustered. That is, no attempt is made to store new or updated rows according to their index order. If you wish, you can periodically recluster by issuing the command again. Setting the table's `FILLFACTOR` storage parameter to less than 100% can aid in preserving cluster ordering during updates, because updated rows are kept on the same page if enough space is available there.

When a table is clustered using this command, WarehousePG remembers on which index it was clustered. The form `CLUSTER <table_name>` reclusters the table on the same index that it was clustered before. You can use the `CLUSTER` or `SET WITHOUT CLUSTER` forms of ALTER TABLE to set the index to use for future cluster operations, or to clear any previous setting. `CLUSTER` without any parameter reclusters all previously clustered tables in the current database that the calling user owns, or all tables if called by a superuser. This form of `CLUSTER` cannot be run inside a transaction block.

When a table is being clustered, an `ACCESS EXCLUSIVE` lock is acquired on it. This prevents any other database operations (both reads and writes) from operating on the table until the `CLUSTER` is finished.

Parameters

index_name The name of an index.

`VERBOSE` Prints a progress report as each table is clustered.

table_name The name (optionally schema-qualified) of a table.

Notes

If the records you need are distributed randomly on disk, then the database has to seek across the disk to get the records requested. If those records are stored more closely together, then the fetching from disk is more sequential. In cases where you are accessing single rows randomly within a table, the actual order of the data in the table is unimportant. However, if you tend to access some data more than others, and there is an index that groups them together, you will benefit from using `CLUSTER`. If you are requesting a range of indexed values from a table, or a single indexed value that has multiple rows that match, `CLUSTER` will help because once the index identifies the table page for the first row that matches, all other rows that match are probably already on the same table page, and so you save disk accesses and speed up the query. A good example for a clustered index is on a date column where the data is ordered sequentially by date. A query against a specific date range will result in an ordered fetch from the disk, which leverages faster sequential access.

`CLUSTER` can re-sort the table using either an index scan on the specified index, or (if the index is a b-tree) a sequential scan followed by sorting. It will attempt to choose the method that will be faster, based on planner cost parameters and available statistical information.

When an index scan is used, a temporary copy of the table is created that contains the table data in the index order. Temporary copies of each index on the table are created as well. Therefore, you need free space on disk at least equal to the sum of the table size and the index sizes.

When a sequential scan and sort is used, a temporary sort file is also created, so that the peak temporary space requirement is as much as double the table size, plus the index sizes. This method is often faster than the index scan method, but if the disk space requirement is intolerable, you can deactivate this choice by temporarily setting the enable_sort configuration parameter to `off`.

It is advisable to set the maintenance_work_mem configuration parameter to a reasonably large value (but not more than the amount of RAM you can dedicate to the `CLUSTER` operation) before clustering.

Because the query optimizer records statistics about the ordering of tables, it is advisable to run ANALYZE on the newly clustered table. Otherwise, the planner may make poor query plan choices.

Because `CLUSTER` remembers which indexes are clustered, you can cluster the tables you want clustered manually the first time, then set up a periodic maintenance script that runs `CLUSTER` without any parameters, so that the desired tables are periodically reclustered.

Examples

Cluster the table `employees` on the basis of its index `emp_ind`:

```
CLUSTER emp_ind ON emp;
```

Cluster the `employees` table using the same index that was used before:

```
CLUSTER employees;
```

Cluster all tables in the database that have previously been clustered:

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```
CLUSTER;
```

Compatibility

There is no `CLUSTER` statement in the SQL standard.

See Also

CREATE TABLE AS, CREATE INDEX

Parent topic: SQL Commands

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7.1.47 COMMENT

Defines or changes the comment of an object.

Synopsis

```
COMMENT ON
{ ACCESS METHOD <object_name> |
  AGGREGATE <aggregate_name> (<aggregate_signature>) |
  CAST (<source_type> AS <target_type>) |
  COLLATION <object_name>
  COLUMN <relation_name>.<column_name> |
  CONSTRAINT <constraint_name> ON <table_name> |
  CONSTRAINT <constraint_name> ON DOMAIN <domain_name> |
  CONVERSION <object_name> |
  DATABASE <object_name> |
  DOMAIN <object_name> |
  EVENT TRIGGER <object_name> |
  EXTENSION <object_name> |
  FOREIGN DATA WRAPPER <object_name> |
  FOREIGN TABLE <object_name> |
  FUNCTION <function_name> [([[<argmode>] [<argname>] <argtype> [, ...]])] |
  INDEX <object_name> |
  MATERIALIZED VIEW <object_name> |
  OPERATOR <operator_name> (<left_type>, <right_type>) |
  OPERATOR CLASS <object_name> USING <index_method> |
  OPERATOR FAMILY <object_name> USING <index_method> |
  POLICY <policy_name> ON <table_name> |
  [PROCEDURAL] LANGUAGE <object_name> |
  PROCEDURE <procedure_name> [([[<argmode>] [<argname>] <argtype> [, ...]])] |
  RESOURCE GROUP <object_name> |
  RESOURCE QUEUE <object_name> |
  ROLE <object_name |
  ROUTINE <routine_name> [([[<argmode>] [<argname>] <argtype> [, ...]])] |
  RULE <rule_name> ON <table_name> |
  SCHEMA <object_name> |
  SEQUENCE <object_name> |
  SERVER <object_name> |
  STATISTICS <object_name> |
  TABLE <object_name> |
  TABLESPACE <object_name> |
  TEXT SEARCH CONFIGURATION <object_name> |
  TEXT SEARCH DICTIONARY <object_name> |
  TEXT SEARCH PARSER <object_name> |
  TEXT SEARCH TEMPLATE <object_name> |
  TRANSFORM FOR <type_name> LANGUAGE <lang_name> |
  TRIGGER <trigger_name> ON <table_name> |
  TYPE <object_name> |
  VIEW <object_name>
} IS { <string_literal> | NULL }

where <aggregate_signature> is:

* |
[ <argmode> ] [ <argname> ] <argtype> [ , ... ] |
[ [ <argmode> ] [ <argname> ] <argtype> [ , ... ] ] ORDER BY [ <argmode> ] [ <argname> ] <argtype> [ , ... ]
```

Description

`COMMENT` stores a comment about a database object. Only one comment string is stored for each object, so to modify a comment, issue a new `COMMENT` command for the same object. To remove a comment, specify `NULL` in place of the text string. Comments are automatically dropped when the object is dropped.

WarehousePG acquires a `SHARE UPDATE EXCLUSIVE` lock on the object to be commented.

For most kinds of object, only the object's owner can set the comment. Roles don't have owners, so the rule for `COMMENT ON ROLE` is that you must be superuser to comment on a superuser role, or have the `CREATEROLE` privilege to comment on non-superuser roles. Likewise, access methods don't have owners either; you must be superuser to comment on an access method. Of course, a superuser can comment on anything.

You can view comments using the `psql` meta-commands `\dd`, `\d+`, and `\l+`. Other user interfaces to retrieve comments can be built atop the same built-in functions that `psql` uses, namely `obj_description()`, `col_description()`, and `shobj_description()`.

Parameters

object_name relation_name.column_name aggregate_name constraint_name function_name operator_name policy_name procedure_name routine_name rule_name trigger_name The name of the object to be commented. Names of tables, aggregates, collations, conversions, domains, foreign tables, functions, indexes, operators, operator classes, operator families, procedures, routines, sequences, statistics, text search objects, types, views, and materialized views can be schema-qualified. When commenting on a column, relation_name must refer to a table, view, materialized view, composite type, or foreign table.

```
> **Note** WarehousePG does not support triggers.
```

table_name domain_name When creating a comment on a constraint, a trigger, a rule, or a policy, these parameters specify the name of the table or domain on which that object is defined.

source_type The name of the source data type of the cast.

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target_type The name of the target data type of the cast.

argmode The mode of a function or aggregate argument: either `IN`, `OUT`, `INOUT`, or `VARIADIC`. If omitted, the default is `IN`. Note that `COMMENT` does not actually pay any attention to `OUT` arguments, since only the input arguments are needed to determine the function's identity. It is sufficient to list the `IN`, `INOUT`, and `VARIADIC` arguments.

argname The name of a function, procedure, or aggregate argument. Note that `COMMENT` does not actually pay any attention to argument names, since only the argument data types are needed to determine the function's identity.

argtype The data type of a function, procedure, or aggregate argument.

left_type right_type The data type(s) of the operator's arguments (optionally schema-qualified). Specify `NONE` for the missing argument of a prefix or postfix operator.

PROCEDURAL WarehousePG ignores this noise word.

type_name The name of the data type of the transform.

lang_name The name of the language of the transform.

string_literal The new comment contents, written as a string literal.

NULL Specify `NULL` to drop the comment.

Notes

There is presently no security mechanism for viewing comments: any user connected to a database can see all of the comments for objects in that database. For shared objects such as databases, roles, and tablespaces, comments are stored globally so any user connected to any database in the cluster can see all the comments for shared objects.

> **Caution** Do not put security-critical information in comments.

Examples

Attach a comment to the table `mytable`:

```
COMMENT ON TABLE mytable IS 'This is my table.';
```

Remove it again:

```
COMMENT ON TABLE mytable IS NULL;
```

More examples:

```
COMMENT ON ACCESS METHOD gin IS 'GIN index access method';
COMMENT ON AGGREGATE my_aggregate (double precision) IS 'Computes sample variance';
COMMENT ON CAST (text AS int4) IS 'Allow casts from text to int4';
COMMENT ON COLLATION "fr_CA" IS 'Canadian French';
COMMENT ON COLUMN my_table.my_column IS 'Employee ID number';
COMMENT ON CONVERSION my_conv IS 'Conversion to UTF8';
COMMENT ON CONSTRAINT bar_col_cons ON bar IS 'Constrains column col';
COMMENT ON CONSTRAINT dom_col_constr ON DOMAIN dom IS 'Constrains col of domain';
COMMENT ON DATABASE my_database IS 'Development Database';
COMMENT ON DOMAIN my_domain IS 'Email Address Domain';
COMMENT ON EVENT TRIGGER cancel_ddl IS 'Cancels all DLL commands';
COMMENT ON EXTENSION hstore IS 'implements the hstore data type';
COMMENT ON FOREIGN DATA WRAPPER mywrapper IS 'my foreign data wrapper';
COMMENT ON FOREIGN TABLE my_foreign_table IS 'Employee Information in other database';
COMMENT ON FUNCTION my_function (timestamp) IS 'Returns Roman Numeral';
COMMENT ON INDEX my_index IS 'Enforces uniqueness on employee ID';
COMMENT ON LANGUAGE plpython IS 'Python support for stored procedures';
COMMENT ON MATERIALIZED VIEW my_matview IS 'Summary of order history';
COMMENT ON OPERATOR ^ (text, text) IS 'Performs intersection of two texts';
COMMENT ON OPERATOR - (NONE, integer) IS 'Unary minus';
COMMENT ON OPERATOR CLASS int4_ops USING btree IS '4 byte integer operators for btrees';
COMMENT ON OPERATOR FAMILY integer_ops USING btree IS 'all integer operators for btrees';
COMMENT ON POLICY my_policy ON mytable IS 'Filter rows by users';
COMMENT ON PROCEDURE my_proc (integer, integer) IS 'Runs a report';
COMMENT ON ROLE my_role IS 'Administration group for finance tables';
COMMENT ON ROUTINE my_routine (integer, integer) IS 'Runs a routine (which is a function or procedure)';
COMMENT ON RULE my_rule ON my_table IS 'Logs updates of employee records';
COMMENT ON SCHEMA my_schema IS 'Departmental data';
COMMENT ON SEQUENCE my_sequence IS 'Used to generate primary keys';
COMMENT ON SERVER myserver IS 'my foreign server';
COMMENT ON STATISTICS my_statistics IS 'Improves planner row estimations';
COMMENT ON TABLE my_schema.my_table IS 'Employee Information';
COMMENT ON TABLESPACE my_tablespace IS 'Tablespace for indexes';
COMMENT ON TEXT SEARCH CONFIGURATION my_config IS 'Special word filtering';
COMMENT ON TEXT SEARCH DICTIONARY swedish IS 'Snowball stemmer for Swedish language';
COMMENT ON TEXT SEARCH PARSER my_parser IS 'Splits text into words';
COMMENT ON TEXT SEARCH TEMPLATE snowball IS 'Snowball stemmer';
COMMENT ON TRANSFORM FOR hstore LANGUAGE plpythonu IS 'Transform between hstore and Python dict';
COMMENT ON TRIGGER my_trigger ON my_table IS 'Used for RI';
COMMENT ON TYPE complex IS 'Complex number data type';
COMMENT ON VIEW my_view IS 'View of departmental costs';
```

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Compatibility

There is no `COMMENT` command in the SQL standard.

Parent topic: SQL Commands

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7.1.48 COMMIT

Commits the current transaction.

Synopsis

```
COMMIT [WORK | TRANSACTION] [AND [NO] CHAIN]
```

Description

`COMMIT` commits the current transaction. All changes made by the transaction become visible to others and are guaranteed to be durable if a crash occurs.

Parameters

WORK TRANSACTION Optional key words. They have no effect.

AND CHAIN If `AND CHAIN` is specified, a new transaction is immediately started with the same transaction characteristics (see SET TRANSACTION) as the just finished one. Otherwise, no new transaction is started.

Notes

Use ROLLBACK to prematurely end a transaction.

Issuing `COMMIT` when not inside a transaction does no harm, but it will provoke a warning message. `COMMIT AND CHAIN` when not inside a transaction is an error.

Examples

To commit the current transaction and make all changes permanent:

```
COMMIT;
```

Compatibility

The command `COMMIT` conforms to the SQL standard. The form `COMMIT TRANSACTION` is a WarehousePG extension.

See Also

BEGIN, END, ROLLBACK, START TRANSACTION

Parent topic: SQL Commands

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7.1.49 COPY

Copies data between a file and a table.

Synopsis

```
COPY <table_name> [(<column_name> [, ...])]
     FROM {'<filename>' | PROGRAM '<command>' | STDIN}
     [ [ WITH ] ( <option> [, ...] ) ]
     [ WHERE <condition> ]
     [ ON SEGMENT ]

COPY { <table_name> [(<column_name> [, ...])] | (<query>)}
     TO {'<filename>' | PROGRAM '<command>' | STDOUT}
     [ [ WITH ] ( <option> [, ...] ) ]
     [ ON SEGMENT ]

where <option> can be one of:

FORMAT <format_name>
FREEZE [ <boolean> ]
DELIMITER '<delimiter_character>'
NULL '<null_string>'
HEADER [ <boolean> ]
QUOTE '<quote_character>'
ESCAPE '<escape_character>'
FORCE_QUOTE { ( <column_name> [, ...] ) | * }
FORCE_NOT_NULL ( <column_name> [, ...] )
FORCE_NULL ( <column_name> [, ...] )
ENCODING '<encoding_name>'
FILL MISSING FIELDS
LOG ERRORS [ SEGMENT REJECT LIMIT <count> [ ROWS | PERCENT ] ]
IGNORE EXTERNAL PARTITIONS
```

Description

`COPY` moves data between WarehousePG tables and standard file-system files. `COPY TO` copies the contents of a table *to* a file (or multiple files based on the segment ID if copying `ON SEGMENT`), while `COPY FROM` copies data *from* a file to a table (appending the data to whatever is in the table already). `COPY TO` can also copy the results of a `SELECT` query.

If a list of columns is specified, `COPY TO` copies only the data in the specified columns to the file. For COPY FROM, each field in the file is inserted, in order, into the specified column. Table columns not specified in the `COPY FROM` column list will receive their default values.

`COPY` with a file name instructs the WarehousePG coordinator host to directly read from or write to a file. The file must be accessible by the operating system user running WarehousePG (typically `gpadmin`) on the coordinator host and the name must be specified from the viewpoint of the server. When `PROGRAM` is specified, the server runs the given command and reads from the standard output of the program, or writes to the standard input of the program. The command must be specified from the viewpoint of the server, and be executable by the `gpadmin` user. When `STDIN` or `STDOUT` is specified, data is transmitted via the connection between the client and the coordinator. `STDIN` and `STDOUT` cannot be used with the `ON SEGMENT` clause.

When `COPY` is used with the `ON SEGMENT` clause, the `COPY TO` causes segments to create individual segment-oriented files, which remain on the segment hosts. The filename argument for `ON SEGMENT` takes the string literal `<SEGID>` (required) and uses either the absolute path or the `<SEG_DATA_DIR>` string literal. When the `COPY` operation is run, the segment IDs and the paths of the segment data directories are substituted for the string literal values.

Using `COPY TO` with a replicated table (`DISTRIBUTED REPLICATED`) as source creates a file with rows from a single segment so that the target file contains no duplicate rows. Using `COPY TO` with the `ON SEGMENT` clause with a replicated table as source creates target files on segment hosts containing all table rows.

The `ON SEGMENT` clause allows you to copy table data to files on segment hosts for use in operations such as migrating data between clusters or performing a backup. Segment data created by the `ON SEGMENT` clause can be restored by tools such as `gpfdist`, which is useful for high speed data loading.

> **Caution** Use of the `ON SEGMENT` clause is recommended for expert users only.

If `SEGMENT REJECT LIMIT` is provided, then a `COPY FROM` operation will operate in single row error isolation mode. In this release, single row error isolation mode only applies to rows in the input file with format errors — for example, extra or missing attributes, attributes of a wrong data type, or invalid client encoding sequences. Constraint errors such as violation of a `NOT NULL`, `CHECK`, or `UNIQUE` constraint will still be handled in 'all-or-nothing' input mode. The user can specify the number of error rows acceptable (on a per-segment basis), after which the entire `COPY FROM` operation will be cancelled and no rows will be loaded. The count of error rows is per-segment, not per entire load operation. If the per-segment reject limit is not reached, then all rows not containing an error will be loaded and any error rows discarded. To keep error rows for further examination, specify the `LOG ERRORS` clause to capture error log information. The error information and the row is stored internally in WarehousePG.

Parameters

table_name The name (optionally schema-qualified) of an existing table.

column_name An optional list of columns to be copied. If no column list is specified, all columns of the table except generated columns will be copied.

When copying in text format, the default, a row of data in a column of type `bytea` can be up to 256MB.

query A SELECT, VALUES, INSERT, UPDATE, or DELETE command whose results are to be copied. Note that parentheses are required around the query. For `INSERT`, `UPDATE`, and `DELETE` queries a `RETURNING` clause must be provided, and the target relation must not have a conditional rule, nor an `ALSO` rule, nor an `INSTEAD` rule that expands to multiple statements.

filename The path name of the input or output file. An input file name can be an absolute or relative path, but an output file name must be an absolute path. Windows users might need to use an `E''` string and double any backslashes used in the path name.

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PROGRAM 'command' Specify a command to run. In `COPY FROM`, the input is read from standard output of the command, and in `COPY TO`, the output is written to the standard input of the command. The command must be specified from the viewpoint of the WarehousePG coordinator host system, and must be executable by the WarehousePG administrator operating system user (`gpadmin`).

The command is invoked by a shell. When passing arguments to the shell command that come from an untrusted source, strip or escape any special characters that have a special meaning for the shell. For security reasons, it is best to use a fixed command string, or at least avoid passing any user input in the string.

When `ON SEGMENT` is specified, the command must be executable on all WarehousePG primary segment hosts by the WarehousePG administrator user (`gpadmin`). The command is run by each WarehousePG segment instance. The `<SEGID>` is required in the command.

See the `ON SEGMENT` clause for information about command syntax requirements and the data that is copied when the clause is specified.

STDIN Specifies that input comes from the client application. The `ON SEGMENT` clause is not supported with `STDIN`.

STDOUT Specifies that output goes to the client application. The `ON SEGMENT` clause is not supported with `STDOUT`.

boolean Specifies whether the selected option should be turned on or off. You can specify `TRUE`, `ON`, or `1` to enable the option, and `FALSE`, `OFF`, or `0` to deactivate it. The boolean value can also be omitted, in which case `TRUE` is assumed.

FORMAT Selects the data format to be read or written: `text`, `csv` (Comma Separated Values), or `binary`. The default is `text`. See File Formats for more information.

FREEZE Requests copying the data with rows already frozen, just as they would be after running the `VACUUM FREEZE` command. This is intended as a performance option for initial data loading. Rows will be frozen only if the table being loaded has been created or truncated in the current subtransaction, there are no cursors open, and there are no older snapshots held by this transaction. It is not currently possible to perform a `COPY FREEZE` on a partitioned table.

Note that all other sessions will immediately be able to see the data once it has been successfully loaded. This violates the normal rules of MVCC visibility and users specifying this option should be aware of the potential problems this might cause.

DELIMITER Specifies the character that separates columns within each row (line) of the file. The default is a tab character in `text` format, a comma in `CSV` format. This must be a single one-byte character. This option is not allowed when using `binary` format.

NULL Specifies the string that represents a null value. The default is `\N` (backslash-N) in `text` format, and an unquoted empty string in `CSV` format. You might prefer an empty string even in `text` format for cases where you don't want to distinguish nulls from empty strings. This option is not allowed when using `binary` format.

```
> **Note** When using `COPY FROM`, WarehousePG stores any data item that matches this string as a null value, so be sure that you use the same string that you specified in `COPY TO`.
```

HEADER Specifies that a file contains a header line with the names of each column in the file. On output, the first line contains the column names from the table, and on input, the first line is ignored. This option is allowed only when using `CSV` format.

QUOTE Specifies the quoting character to be used when a data value is quoted. The default is double-quote. This must be a single one-byte character. This option is allowed only when using `CSV` format.

ESCAPE Specifies the character that should appear before a data character that matches the `QUOTE` value. The default is the same as the `QUOTE` value (so that the quoting character is doubled if it appears in the data). This must be a single one-byte character. This option is allowed only when using `CSV` format.

FORCE_QUOTE Forces quoting to be used for all non-`NULL` values in each specified column. `NULL` output is never quoted. If `*` is specified, non-`NULL` values will be quoted in all columns. This option is allowed only in `COPY TO`, and only when using `CSV` format.

FORCE_NOT_NULL Do not match the specified columns' values against the null string. In the default case where the null string is empty, this means that empty values will be read as zero-length strings rather than nulls, even when they are not quoted. This option is allowed only in `COPY FROM`, and only when using `CSV` format.

FORCE_NULL Match the specified columns' values against the null string, even if it has been quoted, and if a match is found set the value to `NULL`. In the default case where the null string is empty, this converts a quoted empty string into `NULL`. This option is allowed only in `COPY FROM`, and only when using `CSV` format.

ENCODING 'encoding_name' Specifies that the file is encoded in the encoding_name. If this option is omitted, the current client encoding is used. See theNotes below for more details.

WHERE The optional `WHERE` clause has the general form:

```
WHERE condition
```

where condition is any expression that evaluates to a result of type `boolean`. Any row that does not satisfy this condition will not be inserted to the table. A row satisfies the condition if it returns `true` when the actual row values are substituted for any variable references. Currently, subqueries are not allowed in `WHERE` expressions, and the evaluation does not see any changes made by the `COPY` itself (this matters when the expression contains calls to `VOLATILE` functions).

ON SEGMENT Specify individual, segment data files on the segment hosts. Each file contains the table data that is managed by the primary segment instance. For example, when copying data to files from a table with a `COPY TO...ON SEGMENT` command, the command creates a file on the segment host for each segment instance on the host. Each file contains the table data that is managed by the segment instance.

The `COPY` command does not copy data from or to mirror segment instances and segment data files.

The keywords `STDIN` and `STDOUT` are not supported with `ON SEGMENT`.

The `<SEG_DATA_DIR>` and `<SEGID>` string literals are used to specify an absolute path and file name with the following syntax:

```
COPY <table> [TO|FROM] <SEG_DATA_DIR>/<gpdumpname><SEGID>_<suffix> ON SEGMENT;
```

`<SEG\_DATA\_DIR\>` The string literal representing the absolute path of the segment instance data directory for `ON SEGMENT` copying. The angle brackets (`<` and `>`) are part of the string literal used to specify the path. `COPY` replaces the string literal with the segment path(s) when `COPY` is run. An absolute path can be used in place of the `<SEG_DATA_DIR>` string literal.

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```
`<SEGID\>`
The string literal representing the content ID number of the segment instance to be copied when copying `ON SEGMENT`. `<SEGID>` is a required part of the file name when `ON SEGMENT` is specified. The angle brackets are part of the string literal used to specify the file name.
With `COPY TO`, the string literal is replaced by the content ID of the segment instance when the `COPY` command is run.
With `COPY FROM`, specify the segment instance content ID in the name of the file and place that file on the segment instance host. There must be a file for each primary segment instance on each host. When the `COPY FROM` command is run, the data is copied from the file to the segment instance.
```

When the `PROGRAM command` clause is specified, the `<SEGID>` string literal is required in the command, the `<SEG_DATA_DIR>` string literal is optional. See Examples.

For a `COPY FROM...ON SEGMENT` command, the table distribution policy is checked when data is copied into the table. By default, an error is returned if a data row violates the table distribution policy. You can deactivate the distribution policy check with the server configuration parameter `gp_enable_segment_copy_checking`. See Notes.

NEWLINE Specifies the newline used in your data files — `LF` (Line feed, 0x0A), `CR` (Carriage return, 0x0D), or `CRLF` (Carriage return plus line feed, 0x0D 0x0A). If not specified, a WarehousePG segment will detect the newline type by looking at the first row of data it receives and using the first newline type encountered.

FILL MISSING FIELDS In `COPY FROM` more for both `TEXT` and `CSV`, specifying `FILL MISSING FIELDS` will set missing trailing field values to `NULL` (instead of reporting an error) when a row of data has missing data fields at the end of a line or row. Blank rows, fields with a `NOT NULL` constraint, and trailing delimiters on a line will still report an error.

LOG ERRORS This is an optional clause that can precede a `SEGMENT REJECT LIMIT` clause to capture error log information about rows with formatting errors.

Error log information is stored internally and is accessed with the WarehousePG built-in SQL function `gp_read_error_log()`.

See Notes for information about the error log information and built-in functions for viewing and managing error log information.

SEGMENT REJECT LIMIT count [ROWS | PERCENT] Runs a `COPY FROM` operation in single row error isolation mode. If the input rows have format errors they will be discarded provided that the reject limit count is not reached on any WarehousePG segment instance during the load operation. The reject limit count can be specified as number of rows (the default) or percentage of total rows (1-100). If `PERCENT` is used, each segment starts calculating the bad row percentage only after the number of rows specified by the parameter gp_reject_percent_threshold has been processed. The default for `gp_reject_percent_threshold` is 300 rows. Constraint errors such as violation of a `NOT NULL`, `CHECK`, or `UNIQUE` constraint will still be handled in 'all-or-nothing' input mode. If the limit is not reached, all good rows will be loaded and any error rows discarded.

> **Note** WarehousePG limits the initial number of rows that can contain formatting errors if the `SEGMENT REJECT LIMIT` is not triggered first or is not specified. If the first 1000 rows are rejected, the `COPY` operation is stopped and rolled back.

The limit for the number of initial rejected rows can be changed with the WarehousePG server configuration parameter gp_initial_bad_row_limit server configuration parameter documentation for information about the parameter.

IGNORE EXTERNAL PARTITIONS When copying data from partitioned tables, data are not copied from leaf partitions that are external tables. A message is added to the log file when data are not copied.

If this clause is not specified and WarehousePG attempts to copy data from a leaf partition that is an external table, an error is returned.

See the Notes for information about specifying an SQL query to copy data from leaf child partitions that are external tables.

Outputs

On successful completion, a `COPY` command returns a command tag of the form, where `<count>` identifies the number of rows copied:

```
COPY <count>
```

`psql` prints this command tag only if the command was not `COPY ... TO STDOUT`, or the equivalent `psql` meta-command `\copy ... to stdout`. This is to prevent confusing the command tag with the data that was just printed.

If running a `COPY FROM` command in single row error isolation mode, WarehousePG returns the following notice message if any rows were not loaded due to format errors. `<count>` identifies the number of formatting errors and `<n>` identfies the minimum number of rows rejected:

```
NOTICE: found <count> data formatting errors (<n> or more input rows), rejected related input data
```

Notes

`COPY TO` can only be used with plain tables, not with external tables or views, and does not copy rows from child tables or child partitions. For example, `COPY <table> TO` copies the same rows as `SELECT * FROM ONLY <table>`. However, you can write `COPY (SELECT * FROM <viewname>) TO ...` to dump all of the rows in an inheritance hierarchy, partitioned table, or view.

Similarly, to copy data from a partitioned table with a leaf partition that is an external table, use an SQL query to select the data to copy. For example, if the table `my_sales` contains a leaf partition that is an external table, this command `COPY my_sales TO stdout` returns an error. This command sends the data to `stdout`:

```
COPY (SELECT * from my_sales ) TO stdout;
```

`COPY FROM` can be used with plain, foreign, or partitioned tables or with views that have INSTEAD OF INSERT triggers.

You must have `SELECT` privilege on the table whose values are read by `COPY TO`, and `INSERT` privilege on the table into which values are inserted by `COPY FROM`. It is sufficient to have column privileges on the columns listed in the command.

If row-level security is enabled for the table, the relevant `SELECT` policies will apply to `COPY <table> TO` statements. Currently, `COPY FROM` is not supported for tables with row-level security. Use equivalent `INSERT` statements instead.

Files named in a `COPY` command are read or written directly by the database server, not by the client application. Therefore, they must reside on or be accessible to the WarehousePG coordinator host machine, not the client. They must be accessible to and readable or writable by the WarehousePG cluster user (the user ID the server runs as), not the client. Only database superusers are permitted to name files with `COPY`, because this allows reading or writing any file that the server has privileges to access.

Do not confuse `COPY` with the `psql` instruction `\copy`. `\copy` invokes `COPY FROM STDIN` or `COPY TO STDOUT`, and then fetches/stores the data in a file accessible to the `psql` client. Thus, file accessibility and access rights depend on the client rather than the server when `\copy` is used.

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Always specify the file name used in `COPY` as an absolute path. This is enforced by the server in the case of `COPY TO`, but for `COPY FROM` you do have the option of reading from a file specified by a relative path. The path will be interpreted relative to the working directory of the server process (normally the cluster's data directory), not the client's working directory

Executing a command with `PROGRAM` might be restricted by the operating system's access control mechanisms.

`COPY FROM` will invoke any triggers and check constraints on the destination table. However, it will not invoke rules. Note that in this release, violations of constraints are not evaluated for single row error isolation mode.

For identity columns, the `COPY FROM` command will always write the column values provided in the input data, like the `INSERT` option `OVERRIDING SYSTEM VALUE`.

`COPY` input and output is affected by `DateStyle`. To ensure portability to other WarehousePG installations that might use non-default `DateStyle` settings, set `DateStyle` to `ISO` before using `COPY TO`. It is also a good idea to avoid dumping data with `IntervalStyle` set to `sql_standard`, because negative interval values might be misinterpreted by a server that has a different setting for `IntervalStyle`.

Input data is interpreted according to `ENCODING` option or the current client encoding, and output data is encoded in `ENCODING` or the current client encoding, even if the data does not pass through the client but is read from or written to a file directly by the server.

By default, `COPY` stops operation at the first error. This should not lead to problems in the event of a `COPY TO`, but the target table will already have received earlier rows in a `COPY FROM`. These rows will not be visible or accessible, but they still occupy disk space. This may amount to a considerable amount of wasted disk space if the failure happened well into a large `COPY FROM` operation. You may choose to invoke `VACUUM` to recover the wasted space. Another option would be to use single row error isolation mode to filter out error rows while still loading good rows.

`FORCE_NULL` and `FORCE_NOT_NULL` can be used simultaneously on the same column. This results in converting quoted null strings to null values and unquoted null strings to empty strings.

The `BINARY` keyword causes all data to be stored/read as binary format rather than as text. It is somewhat faster than the normal text mode, but a binary-format file is less portable across machine architectures and WarehousePG versions. Also, you cannot run `COPY FROM` in single row error isolation mode if the data is in binary format.

When copying XML data from a file in text mode, the server configuration parameter xmloption affects the validation of the XML data that is copied. If the value is `content` (the default), XML data is validated as an XML content fragment. If the parameter value is `document`, XML data is validated as an XML document. If the XML data is not valid, `COPY` returns an error.

When a `COPY FROM...ON SEGMENT` command is run, the server configuration parameter gp_enable_segment_copy_checking controls whether WarehousePG checks the table distribution policy (from the table `DISTRIBUTED` clause) when data is copied into the table. The default is to check the distribution policy. An error is returned if the row of data violates the distribution policy for the segment instance.

Data from a table that is generated by a `COPY TO...ON SEGMENT` command can be used to restore table data with `COPY FROM...ON SEGMENT`. However, data restored to the segments is distributed according to the table distribution policy at the time the files were generated with the `COPY TO` command. The `COPY` command might return table distribution policy errors, if you attempt to restore table data and the table distribution policy was changed after the `COPY FROM...ON SEGMENT` was run.

> **Note** If you run `COPY FROM...ON SEGMENT` and the server configuration parameter `gp_enable_segment_copy_checking` is `false`, manual redistribution of table data might be required. See the `ALTER TABLE` clause `WITH REORGANIZE`.

When you specify the `LOG ERRORS` clause, WarehousePG captures errors that occur while reading the external table data. You can view and manage the captured error log data.

- Use the built-in SQL function `gp_read_error_log('table\_name')`. It requires `SELECT` privilege on table_name. This example displays the error log information for data loaded into table `ext_expenses` with a `COPY` command:

  ```
  SELECT * from gp_read_error_log('ext_expenses');
  ```

  For information about the error log format, see Viewing Bad Rows in the Error Log in the *WarehousePG Administrator Guide*.

  The function returns `FALSE` if table_name does not exist.

- If error log data exists for the specified table, the new error log data is appended to existing error log data. The error log information is not replicated to mirror segments.

- Use the built-in SQL function `gp_truncate_error_log('table\_name')` to delete the error log data for table_name. It requires the table owner privilege This example deletes the error log information captured when moving data into the table `ext_expenses`:

  ```
  SELECT gp_truncate_error_log('ext_expenses');
  ```

  The function returns `FALSE` if table_name does not exist.

  Specify the `*` wildcard character to delete error log information for existing tables in the current database. Specify the string `*.*` to delete all database error log information, including error log information that was not deleted due to previous database issues. If `*` is specified, database owner privilege is required. If `*.*` is specified, operating system super-user privilege is required.

When a WarehousePG user who is not a superuser runs a `COPY` command, the command can be controlled by a resource queue. The resource queue must be configured with the `ACTIVE_STATEMENTS` parameter that specifies a maximum limit on the number of queries that can be run by roles assigned to that queue. WarehousePG does not apply a cost value or memory value to a `COPY` command, resource queues with only cost or memory limits do not affect the running of `COPY` commands.

A non-superuser can run only these types of `COPY` commands:

- `COPY FROM` command where the source is `stdin`
- `COPY TO` command where the destination is `stdout`

For information about resource queues, refer to Using Resource Queues in the *WarehousePG Administrator Guide*.

File Formats

The file formats supported by `COPY` include text, CSV, and binary.

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Text Format

When the `text` format is used, the data read or written is a text file with one line per table row. Columns in a row are separated by the delimiter_character (tab by default). The column values themselves are strings generated by the output function, or acceptable to the input function, of each attribute's data type. The specified null string is used in place of columns that are null. `COPY FROM` will raise an error if any line of the input file contains more or fewer columns than are expected.

Backslash characters (`\`) can be used in the `COPY` data to quote data characters that might otherwise be taken as row or column delimiters. In particular, the following characters*must* be preceded by a backslash if they appear as part of a column value: backslash itself, newline, carriage return, and the current delimiter character.

The specified null string is sent by `COPY TO` without adding any backslashes; conversely, `COPY FROM` matches the input against the null string before removing backslashes. Therefore, a null string such as `\N` cannot be confused with the actual data value `\N` (which would be represented as `\\N`).

The following special backslash sequences are recognized by `COPY FROM`:

Sequence	Represents
\b	Backspace (ASCII 8)
\f	Form feed (ASCII 12)
\n	Newline (ASCII 10)
\r	Carriage return (ASCII 13)
\t	Tab (ASCII 9)
\v	Vertical tab (ASCII 11)
\digits	Backslash followed by one to three octal digits specifies the byte with that numeric code
\xdigits	Backslash x followed by one or two hex digits specifies the byte with that numeric code

`COPY TO` will never emit an octal or hex-digits backslash sequence, but it does use the other sequences listed above for those control characters.

Any other backslashed character that is not mentioned in the above table will be taken to represent itself. However, beware of adding backslashes unnecessarily, since that might accidentally produce a string matching the end-of-data marker (`\.`) or the null string (`\N` by default). These strings will be recognized before any other backslash processing is done.

Ensure that applications generating `COPY` data convert data newlines and carriage returns to the `\n` and `\r` sequences respectively. It is currently possible to represent a data carriage return by a backslash and carriage return, and to represent a data newline by a backslash and newline. However, these representations might not be accepted in future releases, and they are also highly vulnerable to corruption if the `COPY` file is transferred across different machines (for example, from Unix to Windows or vice versa).

All backslash sequences are interpreted after encoding conversion. The bytes specified with the octal and hex-digit backslash sequences must form valid characters in the database encoding.

`COPY TO` will terminate each row with a Unix-style newline (`\n`). Servers running on Microsoft Windows instead output carriage return/newline (`\r\n`), but only for `COPY` to a server file; for consistency across platforms, `COPY TO STDOUT` always sends `\n` regardless of server platform. `COPY FROM` can handle lines ending with newlines, carriage returns, or carriage return/newlines. To reduce the risk of error due to un-backslashed newlines or carriage returns that were meant as data, `COPY FROM` issues a warning if the line endings in the input are not all alike.

To summarize, two reserved characters have special meaning to `COPY`:

- The designated delimiter character (tab by default), which is used to separate fields in the data file.
- A UNIX-style line feed (`\n` or `0x0a`), which is used to designate a new row in the data file.

By default, the escape character for a text-format file is a `\\` (backslash). If you want to use a different escape character, you can do so using the `ESCAPE` clause. Make sure to choose an escape character that is not used anywhere in your data file as an actual data value. You can also deactivate escaping in text-formatted files by using `ESCAPE 'OFF'`.

If your data contains either of these characters, you must escape the character so `COPY` treats it as data and not as a field separator or new row. The following characters must also be preceded by the escape character if they appear as part of a column value: the escape character itself, newline, carriage return, and the current delimiter character.

For example, suppose you have a table with three columns and you want to load the following three fields using `COPY`.

- percentage sign = %
- vertical bar = |
- backslash = \

Your designated delimiter_character is `|` (pipe character), and your designated escape character is `*` (asterisk). The formatted row in your data file would appear as follows:

```
percentage sign = % | vertical bar = *| | backslash = \
```

Notice how the pipe character that is part of the data has been escaped using the asterisk character (*). Also notice that we do not need to escape the backslash since we are using an alternative escape character.

CSV Format

This format option is used for importing and exporting the Comma Separated Value (CSV) file format used by many other programs, such as spreadsheets. Instead of the escaping rules used by WarehousePG standard text format, it produces and recognizes the common CSV escaping mechanism.

The values in each record are separated by the `DELIMITER` character. If the value contains the delimiter character, the `QUOTE` character, the `ESCAPE` character (which is double quote by default), the `NULL` string, a carriage return, or line feed character, then the whole value is prefixed and suffixed by the `QUOTE` character. You can also use `FORCE_QUOTE` to force quotes when outputting non-`NULL` values in specific columns.

The CSV format has no standard way to distinguish a `NULL` value from an empty string. WarehousePG `COPY` handles this by quoting. A `NULL` is output as the `NULL` parameter string and is not quoted, while a non-`NULL` value matching the `NULL` string is quoted. For example, with the default settings, a `NULL` is written as an unquoted empty string, while an empty string data value is written with double quotes (`""`). Reading values follows similar rules. You can use `FORCE_NOT_NULL` to prevent `NULL` input comparisons for specific columns. You can also use `FORCE_NULL` to convert quoted null string data values to `NULL`.

Because backslash is not a special character in the `CSV` format, `\.`, the end-of-data marker, could also appear as a data value. To avoid any misinterpretation, a `\.` data value appearing as a lone entry on a line is automatically quoted on output, and on input, if quoted, is not interpreted as the end-of-data marker. If you are loading a file created by another application that has a single unquoted column and might have a value of `\.`, you might need to quote that value in the input file.

> **Note** In `CSV` format, all characters are significant. A quoted value surrounded by white space, or any characters other than `DELIMITER`, will include those characters. This can cause errors if you import data from a system

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> that pads CSV lines with white space out to some fixed width. If such a situation arises you might need to preprocess the CSV file to remove the trailing white space, before importing the data into WarehousePG.

`CSV` format will both recognize and produce CSV files with quoted values containing embedded carriage returns and line feeds. The files are not strictly one line per table row like text-format files.

> **Note** Many programs produce strange CSV files, so the file format is more a convention than a standard. You might encounter some files that cannot be imported using this mechanism, and `COPY` might produce files that other programs cannot process.

Binary Format

The `binary` format option causes all data to be stored/read as binary format rather than as text. It is somewhat faster than the text and `CSV` formats, but a binary-format file is less portable across machine architectures and WarehousePG versions. Also, the binary format is very data type specific; for example it will not work to output binary data from a `smallint` column and read it into an `integer` column, even though that would work fine in text format.

The binary file format consists of a file header, zero or more tuples containing the row data, and a file trailer. Headers and data are in network byte order.

File Header

The file header consists of 15 bytes of fixed fields, followed by a variable-length header extension area. The fixed fields are:

Signature 11-byte sequence `PGCOPY\\n\\377\\r\\n\\0` — note that the zero byte is a required part of the signature. (The signature is designed to allow easy identification of files that have been munged by a non-8-bit-clean transfer. This signature will be changed by end-of-line-translation filters, dropped zero bytes, dropped high bits, or parity changes.)

Flags field 32-bit integer bit mask to denote important aspects of the file format. Bits are numbered from 0 (LSB) to 31 (MSB). Note that this field is stored in network byte order (most significant byte first), as are all the integer fields used in the file format. Bits 16-31 are reserved to denote critical file format issues; a reader should cancel if it finds an unexpected bit set in this range. Bits 0-15 are reserved to signal backwards-compatible format issues; a reader should simply ignore any unexpected bits set in this range. Currently only one flag is defined, and the rest must be zero. Bit 16: 1 if data has OIDs, 0 if not. WarehousePG no longer supports OID system columns, but the format still contains the indicator.

Header extension area length 32-bit integer, length in bytes of remainder of header, not including self. Currently, this is zero, and the first tuple follows immediately. Future changes to the format might allow additional data to be present in the header. A reader should silently skip over any header extension data it does not know how to parse. The header extension area is envisioned to contain a sequence of self-identifying chunks. The flags field is not intended to tell readers what is in the extension area.

Tuples

Each tuple begins with a 16-bit integer count of the number of fields in the tuple. (All tuples in a table will have the same count, but that might not always be true.) Then, repeated for each field in the tuple, there is a 32-bit length word followed by that many bytes of field data. (The length word does not include itself, and can be zero.) As a special case, -1 indicates a NULL field value. No value bytes follow in the NULL case.

There is no alignment padding or any other extra data between fields.

All data values in a binary-format file are assumed to be in binary format (format code one). It is anticipated that a future extension may add a header field that allows per-column format codes to be specified.

If OIDs are included in the file, the OID field immediately follows the field-count word. It is a normal field except that it is not included in the field-count. Note that WarehousePG no longer supports OID system columns.

File Trailer

The file trailer consists of a 16-bit integer word containing `-1`. This is easily distinguished from a tuple's field-count word. A reader should report an error if a field-count word is neither `-1` nor the expected number of columns. This provides an extra check against somehow getting out of sync with the data.

Examples

Copy a table to the client using the vertical bar (`|`) as the field delimiter:

```
COPY country TO STDOUT (DELIMITER '|');
```

Copy data from a file into the `country` table:

```
COPY country FROM '/home/usr1/sql/country_data';
```

Copy into a file just the countries whose names start with 'A':

```
COPY (SELECT * FROM country WHERE country_name LIKE 'A%') TO '/home/usr1/sql/a_list_countries.copy';
```

To copy into a compressed file, you can pipe the output through an external compression program:

```
COPY country TO PROGRAM 'gzip > /usr1/proj/bray/sql/country_data.gz';
```

WarehousePG-specific examples START

Copy data from a file into the `sales` table using single row error isolation mode and log errors:

```
COPY sales FROM '/home/usr1/sql/sales_data' LOG ERRORS
   SEGMENT REJECT LIMIT 10 ROWS;
```

To copy segment data for later use, use the `ON SEGMENT` clause. Use of the `COPY ... TO ... ON SEGMENT` command takes the form:

```
COPY <table> TO '<SEG_DATA_DIR>/<gpdumpname><SEGID>_<suffix>' ON SEGMENT;
```

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The `<SEGID>` is required. However, you can substitute an absolute path for the `<SEG_DATA_DIR>` string literal in the path.

When you pass in the string literal `<SEG_DATA_DIR>` and `<SEGID>` to `COPY`, `COPY` will fill in the appropriate values when the operation is run.

For example, if you have `mytable` with the segments and mirror segments like this:

```
contentid | dbid | file segment location
    0     |  1   | /home/usr1/data1/gpsegdir0
    0     |  3   | /home/usr1/data_mirror1/gpsegdir0
    1     |  4   | /home/usr1/data2/gpsegdir1
    1     |  2   | /home/usr1/data_mirror2/gpsegdir1
```

running the command:

```
COPY mytable TO '<SEG_DATA_DIR>/mytable_backup<SEGID>.txt' ON SEGMENT;
```

would result in the following files:

```
/home/usr1/data1/gpsegdir0/mytable_backup0.txt
/home/usr1/data2/gpsegdir1/mytable_backup1.txt
```

The content ID in the first column is the identifier inserted into the file path (for example, `gpsegdir0/mytable_backup0.txt` above) Files are created on the segment hosts, rather than on the coordinator, as they would be in a standard `COPY` operation. No data files are created for the mirror segments when using `ON SEGMENT` copying.

If an absolute path is specified, instead of `<SEG_DATA_DIR>`, such as in the statement

```
COPY mytable TO '/tmp/gpdir/mytable_backup_<SEGID>.txt' ON SEGMENT;
```

files would be placed in `/tmp/gpdir` on every segment. The `gpfdist` tool can also be used to restore data files generated with `COPY TO` with the `ON SEGMENT` option if redistribution is necessary.

> **Note** Tools such as `gpfdist` can be used to restore data. The backup/restore tools will not work with files that were manually generated with `COPY TO ON SEGMENT`.

This example uses a `SELECT` statement to copy data to files on each segment:

```
COPY (SELECT * FROM testtbl) TO '/tmp/mytst<SEGID>' ON SEGMENT;
```

This example copies the data from the `lineitem` table and uses the `PROGRAM` clause to add the data to the `/tmp/lineitem_program.csv` file with `cat` utility. The file is placed on the WarehousePG coordinator.

```
COPY lineitem TO PROGRAM 'cat > /tmp/lineitem.csv' CSV;
```

This example uses the `PROGRAM` and `ON SEGMENT` clauses to copy data to files on the segment hosts. On the segment hosts, the `COPY` command replaces `<SEGID>` with the segment content ID to create a file for each segment instance on the segment host.

```
COPY lineitem TO PROGRAM 'cat > /tmp/lineitem_program<SEGID>.csv' ON SEGMENT CSV;
```

This example uses the `PROGRAM` and `ON SEGMENT` clauses to copy data from files on the segment hosts. The `COPY` command replaces `<SEGID>` with the segment content ID when copying data from the files. On the segment hosts, there must be a file for each segment instance where the file name contains the segment content ID on the segment host.

```
COPY lineitem_4 FROM PROGRAM 'cat /tmp/lineitem_program<SEGID>.csv' ON SEGMENT CSV;
```

WarehousePG-specific examples END

Compatibility

There is no `COPY` statement in the SQL standard.

The following syntax was used in earlier versions of WarehousePG and is still supported:

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```
COPY <table_name> [(<column_name> [, ...])] FROM {'<filename>' | PROGRAM '<command>' | STDIN}
     [ [WITH]
       [ON SEGMENT]
       [BINARY]
       [DELIMITER [ AS ] '<delimiter_character>']
       [NULL [ AS ] '<null string>']
       [HEADER]
       [ESCAPE [ AS ] '<escape>' | 'OFF']
       [NEWLINE [ AS ] 'LF' | 'CR' | 'CRLF']
       [CSV [QUOTE [ AS ] '<quote>']
            [FORCE NOT NULL <column_name> [, ...]]
       [FILL MISSING FIELDS]
       [[LOG ERRORS]
       SEGMENT REJECT LIMIT <count> [ROWS | PERCENT] ]

COPY { <table_name> [(<column_name> [, ...])] | (<query>)} TO {'<filename>' | PROGRAM '<command>' | STDOUT}
      [ [WITH]
        [ON SEGMENT]
        [BINARY]
        [DELIMITER [ AS ] 'delimiter_character']
        [NULL [ AS ] 'null string']
        [HEADER]
        [ESCAPE [ AS ] '<escape>' | 'OFF']
        [CSV [QUOTE [ AS ] 'quote']
             [FORCE QUOTE <column_name> [, ...]] | * ]
      [IGNORE EXTERNAL PARTITIONS ]
```

Note that in this syntax, `BINARY` and `CSV` are treated as independent keywords, not as arguments of a `FORMAT` option.

See Also

CREATE EXTERNAL TABLE

Parent topic: SQL Commands

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7.1.50 CREATE ACCESS METHOD

Defines a new access method.

Synopsis

```
CREATE ACCESS METHOD <name>
    TYPE <access_method_type>
    HANDLER <handler_function>
```

Description

`CREATE ACCESS METHOD` creates a new access method.

The access method name must be unique within the database.

Only superusers can define new access methods.

Parameters

name The name of the access method to create.

access_method_type The type of access method to define. Only `TABLE` and `INDEX` types are supported at present.

handler_function handler_function is the name (possibly schema-qualified) of a previously registered function that represents the access method. The handler function must be declared to take a single argument of type `internal`, and its return type depends on the type of access method; for `TABLE` access methods, it must be `table_am_handler` and for `INDEX` access methods, it must be `index_am_handler`. The C-level API that the handler function must implement varies depending on the type of access method. The table access method API is described in Table Access Method Interface Definition in the PostgreSQL documentation. The index access method API is described in Index Access Method Interface Definition.

Examples

Create an index access method `heptree` with handler function `heptree_handler`:

```
CREATE ACCESS METHOD heptree TYPE INDEX HANDLER
heptree_handler;
```

Compatibility

`CREATE ACCESS METHOD` is a WarehousePG extension.

See Also

DROP ACCESS METHOD, CREATE OPERATOR CLASS, CREATE OPERATOR FAMILY

Parent topic: SQL Commands

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7.1.51 CREATE AGGREGATE

Defines a new aggregate function.

Synopsis

```
CREATE [ OR REPLACE ] AGGREGATE <name> ( [ <argmode> ] [ <argname> ] <arg_data_type> [ , ... ] ) (
    SFUNC = <sfunc>,
    STYPE = <state_data_type>
    [ , SSPACE = <state_data_size> ]
    [ , FINALFUNC = <ffunc> ]
    [ , FINALFUNC_EXTRA ]
    [ , FINALFUNC_MODIFY = { READ_ONLY | SHAREABLE | READ_WRITE } ]
    [ , COMBINEFUNC = <combinefunc> ]
    [ , SERIALFUNC = <serialfunc> ]
    [ , DESERIALFUNC = <deserialfunc> ]
    [ , INITCOND = <initial_condition> ]
    [ , MSFUNC = <msfunc> ]
    [ , MINVFUNC = <minvfunc> ]
    [ , MSTYPE = <mstate_data_type> ]
    [ , MSSPACE = <mstate_data_size> ]
    [ , MFINALFUNC = <mffunc> ]
    [ , MFINALFUNC_EXTRA ]
    [ , MFINALFUNC_MODIFY = { READ_ONLY | SHAREABLE | READ_WRITE } ]
    [ , MINITCOND = <minitial_condition> ]
    [ , SORTOP = <sort_operator> ]
    [ , PARALLEL = { SAFE | RESTRICTED | UNSAFE } ]
    [ , REPSAFE = <boolean> ]
  )

  CREATE [ OR REPLACE ] AGGREGATE <name> ( [ [ <argmode> ] [ <argname> ] <arg_data_type> [ , ... ] ]
      ORDER BY [ <argmode> ] [ <argname> ] <arg_data_type> [ , ... ] ) (
    SFUNC = <sfunc>,
    STYPE = <state_data_type>
    [ , SSPACE = <state_data_size> ]
    [ , FINALFUNC = <ffunc> ]
    [ , FINALFUNC_EXTRA ]
    [ , FINALFUNC_MODIFY = { READ_ONLY | SHAREABLE | READ_WRITE } ]
    [ , COMBINEFUNC = <combinefunc> ]
    [ , INITCOND = <initial_condition> ]
    [ , PARALLEL = { SAFE | RESTRICTED | UNSAFE } ]
    [ , REPSAFE = <boolean> ]
    [ , HYPOTHETICAL ]
  )

  or the old syntax

  CREATE [ OR REPLACE ] AGGREGATE <name> (
    BASETYPE = <base_type>,
    SFUNC = <sfunc>,
    STYPE = <state_data_type>
    [ , SSPACE = <state_data_size> ]
    [ , FINALFUNC = <ffunc> ]
    [ , FINALFUNC_EXTRA ]
    [ , FINALFUNC_MODIFY = { READ_ONLY | SHAREABLE | READ_WRITE } ]
    [ , COMBINEFUNC = <combinefunc> ]
    [ , SERIALFUNC = <serialfunc> ]
    [ , DESERIALFUNC = <deserialfunc> ]
    [ , INITCOND = <initial_condition> ]
    [ , MSFUNC = <msfunc> ]
    [ , MINVFUNC = <minvfunc> ]
    [ , MSTYPE = <mstate_data_type> ]
    [ , MSSPACE = <mstate_data_size> ]
    [ , MFINALFUNC = <mffunc> ]
    [ , MFINALFUNC_EXTRA ]
    [ , MFINALFUNC_MODIFY = { READ_ONLY | SHAREABLE | READ_WRITE } ]
    [ , MINITCOND = <minitial_condition> ]
    [ , SORTOP = <sort_operator> ]
    [ , REPSAFE = <boolean> ]
  )
```

Description

`CREATE AGGREGATE` defines a new aggregate function. `CREATE OR REPLACE AGGREGATE` will either define a new aggregate function or replace an existing definition. Some basic and commonly-used aggregate functions such as `count()`, `min()`, `max()`, `sum()`, `avg()` and so on are already provided in WarehousePG. If you define new types or need an aggregate function not already provided, you can use `CREATE AGGREGATE` to provide the desired features.

When replacing an existing definition, the argument types, result type, and number of direct arguments may not be changed. Also, the new definition must be of the same kind (ordinary aggregate, ordered-set aggregate, or hypothetical-set aggregate) as the old one.

If a schema name is given (for example, `CREATE AGGREGATE myschema.myagg ...`) then the aggregate function is created in the specified schema. Otherwise it is created in the current schema.

An aggregate function is identified by its name and input data type(s). Two aggregate functions in the same schema can have the same name if they operate on different input types. The name and input data type(s) of an aggregate function must also be distinct from the name and input data type(s) of every ordinary function in the same schema. This behavior is identical to overloading of ordinary function names. See CREATE FUNCTION.

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A simple aggregate function is made from one or two ordinary functions; a state transition function sfunc, and an optional final calculation function ffunc.

These functions are used as follows:

```
sfunc( internal-state, next-data-values ) ---> next-internal-state
ffunc( internal-state ) ---> aggregate-value
```

WarehousePG creates a temporary variable of data type state_data_type to hold the current internal state of the aggregate function. At each input row, the aggregate argument value(s) are calculated and the state transition function is invoked with the current state value and the new argument value(s) to calculate a new internal state value. After all the rows have been processed, the final function is invoked once to calculate the aggregate's return value. If there is no final function then the ending state value is returned as-is.

An aggregate function can provide an initial condition, that is, an initial value for the internal state value. This is specified and stored in the database as a value of type `text`, but it must be a valid external representation of a constant of the state value data type. If it is not supplied then the state value starts out null.

If the state transition function is declared `STRICT`, then it cannot be called with null inputs. With such a transition function, aggregate execution behaves as follows. Rows with any null input values are ignored (the function is not called and the previous state value is retained). If the initial state value is null, then at the first row with all non-null input values, the first argument value replaces the state value, and the transition function is invoked at subsequent rows with all non-null input values. This is useful for implementing aggregates like `max()`. Note that this behavior is only available when state_data_type is the same as the first arg_data_type. When these types are different, you must supply a non-null initial condition or use a nonstrict transition function.

If the state transition function is not declared `STRICT`, then it will be called unconditionally at each input row, and must deal with null inputs and null state values for itself. This allows the aggregate author to have full control over the aggregate's handling of null values.

If the final function is declared `STRICT`, then it will not be called when the ending state value is null; instead a null result will be returned automatically. (This is the normal behavior of `STRICT` functions.) In any case the final function has the option of returning a null value. For example, the final function for `avg()` returns null when it sees there were zero input rows.

Sometimes it is useful to declare the final function as taking not just the state value, but extra parameters corresponding to the aggregate's input values. The main reason for doing this is if the final function is polymorphic and the state value's data type would be inadequate to pin down the result type. These extra parameters are always passed as `NULL` (and so the final function must not be strict when the `FINALFUNC_EXTRA` option is used), but nonetheless they are valid parameters. The final function could for example make use of `get_fn_expr_argtype` to identify the actual argument type in the current call.

An aggregate can optionally support *moving-aggregate mode*, as described in Moving-Aggregate Mode in the PostgreSQL documentation. This requires specifying the `MSFUNC`, `MINVFUNC`, and `MSTYPE` functions, and optionally the `MSSPACE`, `MFINALFUNC`, `MFINALFUNC_EXTRA`, `MFINALFUNC_MODIFY`, and `MINITCOND` functions. Except for `MINVFUNC`, these functions work like the corresponding simple-aggregate functions without `M`; they define a separate implementation of the aggregate that includes an inverse transition function.

The syntax with `ORDER BY` in the parameter list creates a special type of aggregate called an *ordered-set aggregate*; or if `HYPOTHETICAL` is specified, then a *hypothetical-set aggregate* is created. These aggregates operate over groups of sorted values in order-dependent ways, so that specification of an input sort order is an essential part of a call. Also, they can have *direct* arguments, which are arguments that are evaluated only once per aggregation rather than once per input row. Hypothetical-set aggregates are a subclass of ordered-set aggregates in which some of the direct arguments are required to match, in number and data types, the aggregated argument columns. This allows the values of those direct arguments to be added to the collection of aggregate-input rows as an additional "hypothetical" row.

An aggregate can optionally support partial aggregation. This requires specifying the `COMBINEFUNC` parameter. If the state_data_type is internal, it's usually also appropriate to provide the `SERIALFUNC` and `DESERIALFUNC` parameters so that parallel aggregation is possible. Note that the aggregate must also be marked `PARALLEL SAFE` to enable parallel aggregation.

Aggregates that behave like `min()` or `max()` can sometimes be optimized by looking into an index instead of scanning every input row. If this aggregate can be so optimized, indicate it by specifying a*sort operator*. The basic requirement is that the aggregate must yield the first element in the sort ordering induced by the operator; in other words:

```
SELECT agg(col) FROM tab;
```

must be equivalent to:

```
SELECT col FROM tab ORDER BY col USING sortop LIMIT 1;
```

Further assumptions are that the aggregate function ignores null inputs, and that it delivers a null result if and only if there were no non-null inputs. Ordinarily, a data type's `<` operator is the proper sort operator for `min()`, and `>` is the proper sort operator for `max()`. Note that the optimization will never actually take effect unless the specified operator is the "less than" or "greater than" strategy member of a B-tree index operator class.

To be able to create an aggregate function, you must have `USAGE` privilege on the argument types, the state type(s), and the return type, as well as `EXECUTE` privilege on the supporting functions.

You can specify `combinefunc` as a method for optimizing aggregate execution. By specifying `combinefunc`, the aggregate can be run in parallel on segments first and then on the coordinator. When a two-level execution is performed, the `sfunc` is run on the segments to generate partial aggregate results, and `combinefunc` is run on the coordinator to aggregate the partial results from segments. If single-level aggregation is performed, all the rows are sent to the coordinator and the `sfunc` is applied to the rows.

Single-level aggregation and two-level aggregation are equivalent execution strategies. Either type of aggregation can be implemented in a query plan. When you implement the functions `combinefunc` and `sfunc`, you must ensure that the invocation of the `sfunc` on the segment instances followed by `combinefunc` on the coordinator produce the same result as single-level aggregation that sends all the rows to the coordinator and then applies only the `sfunc` to the rows.

Parameters

name The name (optionally schema-qualified) of the aggregate function to create.

argmode The mode of an argument: `IN` or `VARIADIC`. (Aggregate functions do not support `OUT` arguments.) If omitted, the default is `IN`. Only the last argument can be marked `VARIADIC`.

argname The name of an argument. This is currently only useful for documentation purposes. If omitted, the argument has no name.

arg_data_type An input data type on which this aggregate function operates. To create a zero-argument aggregate function, write `*` in place of the list of argument specifications. (An example of such an aggregate is `count(*)`.)

base_type In the old syntax for `CREATE AGGREGATE`, the input data type is specified by a `basetype` parameter rather than being written next to the aggregate name. Note that this syntax allows only one input parameter. To define a zero-argument aggregate function with this syntax, specify the `basetype` as `"ANY"` (not `*`). Ordered-set aggregates cannot be defined with the old syntax.

sfunc The name of the state transition function to be called for each input row. For a normal N-argument aggregate function, the state transition function `sfunc` must take N+1 arguments, the first being of type state_data_type and the rest matching the declared input data type(s) of the aggregate. The function must return a value of type state_data_type. This function takes the current state value and the current input data value(s), and returns the next state value.

For ordered-set (including hypothetical-set) aggregates, the state transition function receives only the current state value and the aggregated arguments, not the direct arguments. Otherwise it is the same.

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state_data_type The data type for the aggregate's state value.

state_data_size The approximate average size (in bytes) of the aggregate's state value. If this parameter is omitted or is zero, a default estimate is used based on the state_data_type. The planner uses this value to estimate the memory required for a grouped aggregate query. The planner will consider using hash aggregation for such a query only if the hash table is estimated to fit in work_mem; therefore, large values of this parameter discourage use of hash aggregation.

ffunc The name of the final function called to compute the aggregate result after all input rows have been traversed. The function must take a single argument of type state_data_type. The return data type of the aggregate is defined as the return type of this function. If `ffunc` is not specified, then the ending state value is used as the aggregate result, and the return type is state_data_type.

For ordered-set (including hypothetical-set) aggregates, the final function receives not only the final state value, but also the values of all the direct arguments.

If `FINALFUNC_EXTRA` is specified, then in addition to the final state value and any direct arguments, the final function receives extra NULL values corresponding to the aggregate's regular (aggregated) arguments. This is mainly useful to allow correct resolution of the aggregate result type when a polymorphic aggregate is being defined.

FINALFUNC_MODIFY = { READ_ONLY | SHAREABLE | READ_WRITE } This option specifies whether the final function is a pure function that does not modify its arguments. `READ_ONLY` indicates it does not; the other two values indicate that it may change the transition state value. See Notes below for more detail. The default is `READ_ONLY`, except for ordered-set aggregates, for which the default is `READ_WRITE`.

combinefunc The combinefunc function may optionally be specified to allow the aggregate function to support partial aggregation. If provided, the combinefunc must combine two state_data_type values, each containing the result of aggregation over some subset of the input values, to produce a new state_data_type that represents the result of aggregating over both sets of inputs. This function can be thought of as an sfunc, where instead of acting upon an individual input row and adding it to the running aggregate state, it adds another aggregate state to the running state. The combinefunc must be declared as taking two arguments of the state_data_type and returning a value of the state_data_type. Optionally this function may be "strict". In this case the function will not be called when either of the input states are null; the other state will be taken as the correct result. For aggregate functions whose state_data_type is `internal`, the combinefunc must not be strict. In this case the combinefunc must ensure that null states are handled correctly and that the state being returned is properly stored in the aggregate memory context. In WarehousePG, if the result of the aggregate function is computed in a segmented fashion, the combine function is invoked on the individual internal states in order to combine them into an ending internal state. Note that this function is also called in hash aggregate mode within a segment. Therefore, if you call this aggregate function without a combine function, hash aggregate is never chosen. Since hash aggregate is efficient, consider defining a combine function whenever possible.

serialfunc An aggregate function whose state_data_type is `internal` can participate in parallel aggregation only if it has a serialfunc function, which must serialize the aggregate state into a `bytea` value for transmission to another process. This function must take a single argument of type `internal` and return type `bytea`. A corresponding deserialfunc is also required.

deserialfunc Deserialize a previously serialized aggregate state back into state_data_type. This function must take two arguments of types `bytea` and `internal`, and produce a result of type `internal`. (Note: the second, `internal` argument is unused, but is required for type safety reasons.)

initial_condition The initial setting for the state value. This must be a string constant in the form accepted for the data type state_data_type. If not specified, the state value starts out null.

msfunc The name of the forward state transition function to be called for each input row in moving-aggregate mode. This is exactly like the regular transition function, except that its first argument and result are of type mstate_data_type, which might be different from state_data_type.

minvfunc The name of the inverse state transition function to be used in moving-aggregate mode. This function has the same argument and result types as msfunc, but it is used to remove a value from the current aggregate state, rather than add a value to it. The inverse transition function must have the same strictness attribute as the forward state transition function.

mstate_data_type The data type for the aggregate's state value, when using moving-aggregate mode.

mstate_data_size The approximate average size (in bytes) of the aggregate's state value, when using moving-aggregate mode. This works the same as state_data_size.

mffunc The name of the final function called to compute the aggregate's result after all input rows have been traversed, when using moving-aggregate mode. This works the same as ffunc, except that its first argument's type is mstate_data_type and extra dummy arguments are specified by writing `MFINALFUNC_EXTRA`. The aggregate result type determined by mffunc or mstate_data_type must match that determined by the aggregate's regular implementation.

MFINALFUNC_MODIFY = { READ_ONLY | SHAREABLE | READ_WRITE } This option is like `FINALFUNC_MODIFY`, but it describes the behavior of the moving-aggregate final function.

minitial_condition The initial setting for the state value, when using moving-aggregate mode. This works the same as initial_condition.

sort_operator The associated sort operator for a `min()`- or `max()`-like aggregate. This is just an operator name (possibly schema-qualified). The operator is assumed to have the same input data types as the aggregate (which must be a single-argument normal aggregate).

PARALLEL = { SAFE | RESTRICTED | UNSAFE } The meanings of `PARALLEL SAFE`, `PARALLEL RESTRICTED`, and `PARALLEL UNSAFE` are the same as in CREATE FUNCTION. An aggregate will not be considered for parallelization if it is marked `PARALLEL UNSAFE` (which is the default!) or `PARALLEL RESTRICTED`. Note that the parallel-safety markings of the aggregate's support functions are not consulted by the planner, only the marking of the aggregate itself.

REPSAFE = boolean Specifies whether or not the aggregate can be safely executed on replicated slices. An order-agnostic aggregate would be considered safe in this context. The default value is `false`. Setting `REPSAFE = true` instructs the optimizer to perform additional optimizations that specifically suppress certain broadcast motions.

```
> **Caution** Incorrectly setting `REPSAFE = true` for an order-dependent aggregate may produce incorrect results.
```

HYPOTHETICAL For ordered-set aggregates only, this flag specifies that the aggregate arguments are to be processed according to the requirements for hypothetical-set aggregates: that is, the last few direct arguments must match the data types of the aggregated (`WITHIN GROUP`) arguments. The `HYPOTHETICAL` flag has no effect on run-time behavior, only on parse-time resolution of the data types and collations of the aggregate's arguments.

The parameters of `CREATE AGGREGATE` can be written in any order, not just the order illustrated above.

Notes

The ordinary functions used to define a new aggregate function must be defined first.

If the value of the WarehousePG server configuration parameter `gp_enable_multiphase_agg` is `off`, only single-level aggregation is performed by the Postgres-based planner. There is no equivalent parameter for GPORCA.

Any compiled code (shared library files) for custom functions must be placed in the same location on every host in your WarehousePG cluster (coordinator and all segments). This location must also be in the `LD_LIBRARY_PATH` so that the server can locate the files.

In previous versions of WarehousePG, there was a concept of ordered aggregates. Since version 6, any aggregate can be called as an ordered aggregate, using the syntax:

```
name ( arg [ , ... ] [ORDER BY sortspec [ , ...]] )
```

The `ORDERED` keyword is accepted for backwards compatibility, but is ignored.

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In previous versions of WarehousePG, the `COMBINEFUNC` option was called `PREFUNC`. It is still accepted for backwards compatibility, as a synonym for `COMBINEFUNC`.

Example

The following simple example creates an aggregate function that computes the sum of two columns.

Before creating the aggregate function, create two functions that are used as the `sfunc` and `combinefunc` functions of the aggregate function.

This function is specified as the `sfunc` function in the aggregate function.

```
CREATE FUNCTION mysfunc_accum(numeric, numeric, numeric)
  RETURNS numeric
   AS 'select $1 + $2 + $3'
   LANGUAGE SQL
   RETURNS NULL ON NULL INPUT;
```

This function is specified as the `combinefunc` function in the aggregate function.

```
CREATE FUNCTION mycombine_accum(numeric, numeric )
  RETURNS numeric
   AS 'select $1 + $2'
   LANGUAGE SQL
   RETURNS NULL ON NULL INPUT;
```

This `CREATE AGGREGATE` command creates the aggregate function that adds two columns.

```
CREATE AGGREGATE agg_twocols(numeric, numeric) (
   SFUNC = mysfunc_accum,
   STYPE = numeric,
   COMBINEFUNC = mycombine_accum,
   INITCOND = 0 );
```

The following commands create a table, adds some rows, and runs the aggregate function.

```
CREATE TABLE t1 (a int, b int) DISTRIBUTED BY (a);
INSERT INTO t1 VALUES
   (10, 1),
   (20, 2),
   (30, 3);
SELECT agg_twocols(a, b) FROM t1;
```

Refer to User-Defined Aggregates in the PostgreSQL documentation for more examples of creating aggregates.

Compatibility

`CREATE AGGREGATE` is a WarehousePG language extension. The SQL standard does not provide for user-defined aggregate functions.

See Also

ALTER AGGREGATE, DROP AGGREGATE, CREATE FUNCTION

Parent topic: SQL Commands

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7.1.52 CREATE CAST

Defines a new cast.

Synopsis

```
CREATE CAST (<sourcetype> AS <targettype>)
       WITH FUNCTION <funcname> (<argtype> [, ...])
       [AS ASSIGNMENT | AS IMPLICIT]

CREATE CAST (<sourcetype> AS <targettype>)
       WITHOUT FUNCTION
       [AS ASSIGNMENT | AS IMPLICIT]

CREATE CAST (<sourcetype> AS <targettype>)
       WITH INOUT
       [AS ASSIGNMENT | AS IMPLICIT]
```

Description

`CREATE CAST` defines a new cast. A cast specifies how to perform a conversion between two data types. For example,

```
SELECT CAST(42 AS float8);
```

converts the integer constant `42` to type `float8` by invoking a previously specified function, in this case `float8(int4)`. If no suitable cast has been defined, the conversion fails.

Two types may be binary coercible, which means that the types can be converted into one another without invoking any function. This requires that corresponding values use the same internal representation. For instance, the types `text` and `varchar` are binary coercible in both directions. Binary coercibility is not necessarily a symmetric relationship. For example, the cast from `xml` to `text` can be performed for free in the present implementation, but the reverse direction requires a function that performs at least a syntax check. (Two types that are binary coercible both ways are also referred to as binary compatible.)

You can define a cast as an *I/O conversion cast* by using the `WITH INOUT` syntax. An I/O conversion cast is performed by invoking the output function of the source data type, and passing the resulting string to the input function of the target data type. In many common cases, this feature avoids the need to write a separate cast function for conversion. An I/O conversion cast acts the same as a regular function-based cast; only the implementation is different.

By default, a cast can be invoked only by an explicit cast request, that is an explicit `CAST(x AS` typename `)` or `x:: typename` construct.

If the cast is marked `AS ASSIGNMENT` then it can be invoked implicitly when assigning a value to a column of the target data type. For example, supposing that `foo.f1` is a column of type `text`, then:

```
INSERT INTO foo (f1) VALUES (42);
```

will be allowed if the cast from type `integer` to type `text` is marked `AS ASSIGNMENT`, otherwise not. The term *assignment cast* is typically used to describe this kind of cast.

If the cast is marked `AS IMPLICIT` then it can be invoked implicitly in any context, whether assignment or internally in an expression. The term *implicit cast* is typically used to describe this kind of cast. For example, consider this query:

```
SELECT 2 + 4.0;
```

The parser initially marks the constants as being of type `integer` and `numeric`, respectively. There is no `integer + numeric` operator in the system catalogs, but there is a `numeric + numeric` operator. This query succeeds if a cast from `integer` to `numeric` exists (it does) and is marked `AS IMPLICIT`, which in fact it is. The parser applies only the implicit cast and resolves the query as if it had been written as the following:

```
SELECT CAST ( 2 AS numeric ) + 4.0;
```

The catalogs also provide a cast from `numeric` to `integer`. If that cast were marked `AS IMPLICIT`, which it is not, then the parser would be faced with choosing between the above interpretation and the alternative of casting the `numeric` constant to `integer` and applying the `integer + integer` operator. Lacking any knowledge of which choice to prefer, the parser would give up and declare the query ambiguous. The fact that only one of the two casts is implicit is the way in which we teach the parser to prefer resolution of a mixed `numeric`-and-`integer` expression as `numeric`; the parser has no built-in knowledge about that.

It is wise to be conservative about marking casts as implicit. An overabundance of implicit casting paths can cause WarehousePG to choose surprising interpretations of commands, or to be unable to resolve commands at all because there are multiple possible interpretations. A good general rule is to make a cast implicitly invokable only for information-preserving transformations between types in the same general type category. For example, the cast from `int2` to `int4` can reasonably be implicit, but the cast from `float8` to `int4` should probably be assignment-only. Cross-type-category casts, such as `text` to `int4`, are best made explicit-only.

> **Note** Sometimes it is necessary for usability or standards-compliance reasons to provide multiple implicit casts among a set of types, resulting in ambiguity that cannot be avoided as described above. The parser uses a fallback heuristic based on type categories and preferred types that helps to provide desired behavior in such cases. See CREATE TYPE for more information.

To be able to create a cast, you must own the source or the target data type and have `USAGE` privilege on the other type. To create a binary-coercible cast, you must be superuser. (This restriction is made because an erroneous binary-coercible cast conversion can easily crash the server.)

Parameters

sourcetype The name of the source data type of the cast.

targettype The name of the target data type of the cast.

funcname(argtype [, ...]) The function used to perform the cast. The function name may be schema-qualified. If it is not, WarehousePG looks for the function in the schema search path. The function's result data type must match the target type of the cast.

Cast implementation functions may have one to three arguments. The first argument type must be identical to or binary-coercible from the cast's source type. The second argument, if present, must be type `integer`; it receives the type modifier associated with the destination type, or `-1` if there is none. The third argument, if present, must be type `boolean`; it receives `true` if the cast is an explicit cast, `false` otherwise. The SQL specification demands different behaviors for explicit and implicit casts in some cases. This argument is supplied for functions that must implement such casts. It is not recommended that you design your own data types this way.

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The return type of a cast function must be identical to or binary-coercible to the cast's target type.

Ordinarily a cast must have different source and target data types. However, you are permitted to declare a cast with identical source and target types if it has a cast implementation function that takes more than one argument. This is used to represent type-specific length coercion functions in the system catalogs. The named function is used to coerce a value of the type to the type modifier value given by its second argument.

When a cast has different source and target types and a function that takes more than one argument, the cast converts from one type to another and applies a length coercion in a single step. When no such entry is available, coercion to a type that uses a type modifier involves two steps, one to convert between data types and a second to apply the modifier.

A cast to or from a domain type currently has no effect. Casting to or from a domain uses the casts associated with its underlying type.

WITHOUT FUNCTION Indicates that the source type is binary-coercible to the target type, so no function is required to perform the cast.

WITH INOUT Indicates that the cast is an I/O conversion cast, performed by invoking the output function of the source data type, and passing the resulting string to the input function of the target data type.

AS ASSIGNMENT Indicates that the cast may be invoked implicitly in assignment contexts.

AS IMPLICIT Indicates that the cast may be invoked implicitly in any context.

Notes

Note that in this release of WarehousePG, user-defined functions used in a user-defined cast must be defined as `IMMUTABLE`. Any compiled code (shared library files) for custom functions must be placed in the same location on every host in your WarehousePG cluster (coordinator and all segments). This location must also be in the `LD_LIBRARY_PATH` so that the server can locate the files.

Remember that if you want to be able to convert types both ways you need to declare casts both ways explicitly.

It is normally not necessary to create casts between user-defined types and the standard string types (`text`, `varchar`, and `char(*n*)`, as well as user-defined types that are defined to be in the string category). WarehousePG provides automatic I/O conversion casts for these. The automatic casts to string types are treated as assignment casts, while the automatic casts from string types are explicit-only. You can override this behavior by declaring your own cast to replace an automatic cast, but usually the only reason to do so is if you want the conversion to be more easily invokable than the standard assignment-only or explicit-only setting. Another possible reason is that you want the conversion to behave differently from the type's I/O function - think twice before doing this. (A small number of the built-in types do indeed have different behaviors for conversions, mostly because of requirements of the SQL standard.)

It is recommended that you follow the convention of naming cast implementation functions after the target data type, as the built-in cast implementation functions are named. Many users are used to being able to cast data types using a function-style notation, that is `typename(x)`.

There are two cases in which a function-call construct is treated as a cast request without having matched it to an actual function. If a function call `*name\(x\)*` does not exactly match any existing function, but `*name*` is the name of a data type and `pg_cast` provides a binary-coercible cast to this type from the type of `*x*`, then the call will be construed as a binary-coercible cast. WarehousePG makes this exception so that binary-coercible casts can be invoked using functional syntax, even though they lack any function. Likewise, if there is no `pg_cast` entry but the cast would be to or from a string type, the call is construed as an I/O conversion cast. This exception allows I/O conversion casts to be invoked using functional syntax.

There is an exception to the exception above: I/O conversion casts from composite types to string types cannot be invoked using functional syntax, but must be written in explicit cast syntax (eithe `CAST` or :: notation). This exception exists because after the introduction of automatically-provided I/O conversion casts, it was found to be too easy to accidentally invoke such a cast when you intended a function or column reference.

Examples

To create an assignment cast from type `bigint` to type `int4` using the function `int4(bigint)` (This cast is already predefined in the system.):

```
CREATE CAST (bigint AS int4) WITH FUNCTION int4(bigint) AS ASSIGNMENT;
```

Compatibility

The `CREATE CAST` command conforms to the SQL standard, except that SQL does not make provisions for binary-coercible types or extra arguments to implementation functions. `AS IMPLICIT` is a WarehousePG extension, too.

See Also

CREATE FUNCTION, CREATE TYPE, DROP CAST

Parent topic: SQL Commands

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7.1.53 CREATE COLLATION

Defines a new collation.

Synopsis

```
CREATE COLLATION [ IF NOT EXISTS ] <name> (
    [ LOCALE = <locale>, ]
    [ LC_COLLATE = <lc_collate>, ]
    [ LC_CTYPE = <lc_ctype>, ]
    [ PROVIDER = <provider>, ]
    [ DETERMINISTIC = <boolean>, ]
    [ VERSION = <version> ])

CREATE COLLATION [ IF NOT EXISTS ] <name> FROM <existing_collation>
```

Description

`CREATE COLLATION` defines a new collation using the specified operating system locale settings, or by copying an existing collation.

To be able to create a collation, you must have `CREATE` privilege on the destination schema.

Parameters

IF NOT EXISTS Do not throw an error if a collation with the same name already exists. A notice is issued in this case. Note that there is no guarantee that the existing collation is anything like the one that would have been created.

name The name of the collation. The collation name can be schema-qualified. If it is not, the collation is defined in the current schema. The collation name must be unique within that schema. (The system catalogs can contain collations with the same name for other encodings, but these are ignored if the database encoding does not match.)

locale This is a shortcut for setting `LC_COLLATE` and `LC_CTYPE` at once. If you specify this, you cannot specify either of those parameters.

lc_collate Use the specified operating system locale for the `LC_COLLATE` locale category.

lc_ctype Use the specified operating system locale for the `LC_CTYPE` locale category.

provider Specifies the provider to use for locale services associated with this collation. Possible values are: `icu` , `libc` . `libc` is the default. The available choices depend on the operating system and build options.

DETERMINISTIC Specifies whether the collation should use deterministic comparisons. The default is `true` . A deterministic comparison considers strings that are not byte-wise equal to be unequal even if they are considered logically equal by the comparison. WarehousePG breaks ties using a byte-wise comparison. Comparison that is not deterministic can make the collation be, say, case- or accent-insensitive. For that, you need to choose an appropriate `LC_COLLATE` setting and set the collation to not deterministic here. Nondeterministic collations are only supported with the `icu` provider.

version Specifies the version string to store with the collation. Normally, this should be omitted, which will cause the version to be computed from the actual version of the collation as provided by the operating system. This option is intended to be used by `pg_upgrade` for copying the version from an existing installation. See also ALTER COLLATION for how to handle collation version mismatches.

existing_collation The name of an existing collation to copy. The new collation will have the same properties as the existing one, but it will be an independent object.

Notes

`CREATE COLLATION` takes a `SHARE ROW EXCLUSIVE` lock, which is self-conflicting, on the `pg_collation` system catalog, so only one `CREATE COLLATION` command can run at a time.

Use DROP COLLATION to remove user-defined collations.

See Collation Support in the PostgreSQL documentation for more information about collation support in WarehousePG.

When using the `libc` collation provider, the, locale must be applicable to the current database encoding. See CREATE DATABASE for the precise rules.

Examples

To create a collation from the operating system locale `fr_FR.utf8` (assuming the current database encoding is `UTF8`):

```
CREATE COLLATION french (LOCALE = 'fr_FR.utf8');
```

To create a collation using the `icu` provider using German phone book sort order:

```
CREATE COLLATION german_phonebook (provider = icu, locale = 'de-u-co-phonebk');
```

To create a collation from an existing collation:

```
CREATE COLLATION german FROM "de_DE";
```

This can be convenient to be able to use operating-system-independent collation names in applications.

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Compatibility

There is a `CREATE COLLATION` statement in the SQL standard, but it is limited to copying an existing collation. The syntax to create a new collation is a WarehousePG extension.

See Also

ALTER COLLATION, DROP COLLATION

Parent topic: SQL Commands

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7.1.54 CREATE CONVERSION

Defines a new encoding conversion.

Synopsis

```
CREATE [DEFAULT] CONVERSION <name>
     FOR <source_encoding> TO <dest_encoding> FROM <function_name>
```

Description

`CREATE CONVERSION` defines a new conversion between character set encodings. Also, conversions that are marked `DEFAULT` can be used for automatic encoding conversion between client and server. For this purpose, two conversions, from encoding A to B *and* from encoding B to A, must be defined.

To create a conversion, you must have `EXECUTE` privilege on the function and `CREATE` privilege on the destination schema.

Parameters

DEFAULT Indicates that this conversion is the default for this particular source to destination encoding. There should be only one default encoding in a schema for the encoding pair.

name The name of the conversion. The conversion name may be schema-qualified. If it is not, the conversion is defined in the current schema. The conversion name must be unique within a schema.

source_encoding The source encoding name.

dest_encoding The destination encoding name.

function_name The function used to perform the conversion. The function name may be schema-qualified. If it is not, the function will be looked up in the path. The function must have the following signature:

```
conv_proc(
    integer,  -- source encoding ID
    integer,  -- destination encoding ID
    cstring,  -- source string (null terminated C string)
    internal, -- destination (fill with a null terminated C string)
    integer   -- source string length
) RETURNS void;
```

Notes

Use DROP CONVERSION to remove a user-defined conversion.

The privileges required to create a conversion might change in a feature release.

Note that in this release of WarehousePG, user-defined functions used in a user-defined conversion must be defined as `IMMUTABLE`. Any compiled code (shared library files) for custom functions must be placed in the same location on every host in your WarehousePG cluster (coordinator and all segments). This location must also be in the `LD_LIBRARY_PATH` so that the server can locate the files.

Examples

To create a conversion from encoding `UTF8` to `LATIN1` using `myfunc`:

```
CREATE CONVERSION myconv FOR 'UTF8' TO 'LATIN1' FROM myfunc;
```

Compatibility

`CREATE CONVERSION` is a WarehousePG extension. There is no `CREATE CONVERSION` statement in the SQL standard, but there is a `CREATE TRANSLATION` statement that is very similar in purpose and syntax.

See Also

ALTER CONVERSION, CREATE FUNCTION, DROP CONVERSION

Parent topic: SQL Commands

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7.1.55 CREATE DATABASE

Creates a new database.

Synopsis

```
CREATE DATABASE name
    [ [WITH] [OWNER [=] <user_name>]
          [TEMPLATE [=] <template>]
          [ENCODING [=] <encoding>]
          [LC_COLLATE [=] <lc_collate>]
          [LC_CTYPE [=] <lc_ctype>]
          [TABLESPACE [=] <tablespace_name>]
          [ALLOW_CONNECTIONS [=] <allowconn>]
          [CONNECTION LIMIT [=] <connlimit> ]
          [IS_TEMPLATE [=] <istemplate> ] ]
```

Description

`CREATE DATABASE` creates a new database.

To create a database, you must be a superuser or have the special `CREATEDB` privilege. See CREATE ROLE.

The creator becomes the owner of the new database by default. Superusers can create databases owned by other users by using the `OWNER` clause. They can even create databases owned by users with no special privileges. Non-superusers with `CREATEDB` privilege can only create databases owned by themselves.

By default, the new database will be created by cloning the standard system database `template1`. A different template can be specified by writing `TEMPLATE name`. In particular, by writing `TEMPLATE template0`, you can create a clean database containing only the standard objects predefined by WarehousePG. This is useful if you wish to avoid copying any installation-local objects that may have been added to `template1`.

Parameters

name The name of a database to create.

user_name The name of the database user who will own the new database, or `DEFAULT` to use the default owner (the user running the command). To create a database owned by another role, you must be a direct or indirect member of that role, or be a superuser.

template The name of the template from which to create the new database, or `DEFAULT` to use the default template (template1).

encoding Character set encoding to use in the new database. Specify a string constant (such as `'SQL_ASCII'`), an integer encoding number, or `DEFAULT` to use the default encoding (namely, the encoding of the template database). For more information, see Character Set Support. Refer to the Notes for additional restrictions.

lc_collate The collation order (`LC_COLLATE`) to use in the new database. This affects the sort order applied to strings, e.g. in queries with `ORDER BY`, as well as the order used in indexes on text columns. The default is to use the collation order of the template database. See the Notes for additional restrictions.

lc_ctype The character classification (`LC_CTYPE`) to use in the new database. This affects the categorization of characters, e.g. lower, upper, and digit. The default is to use the character classification of the template database. See the Notes for additional restrictions.

tablespace_name The name of the tablespace that will be associated with the new database, or `DEFAULT` to use the template database's tablespace. This tablespace will be the default tablespace used for objects created in this database. See CREATE TABLESPACE for more information.

allowconn If `false`, then no one can connect to this database. The default is `true`, allowing connections (except as restricted by other mechanisms, such as `GRANT/REVOKE CONNECT`).

connlimit The maximum number of concurrent connections allowed to this database on the coordinator. The default is `-1`, no limit. WarehousePG superusers are exempt from this limit.

istemplate If `true`, then this database can be cloned by any user with `CREATEDB` privileges; if `false` (the default), then only superusers or the owner of the database can clone it. Note that template databases cannot be dropped.

Optional parameters can be written in any order, not only the order illustrated above.

Notes

`CREATE DATABASE` cannot be run inside a transaction block.

Errors along the line of “could not initialize database directory” are most likely related to insufficient permissions on the data directory, a full disk, or other file system problems.

Use DROP DATABASE to remove a database.

The program createdb is a wrapper program around this command, provided for convenience.

Database-level configuration parameters (set via ALTER DATABASE and database-level permissions (set via GRANT) are not copied from the template database.

Although it is possible to copy a database other than `template1` by specifying its name as the template, this is not (yet) intended as a general-purpose `“COPY DATABASE”` facility. The principal limitation is that no other sessions can be connected to the template database while it is being copied. `CREATE DATABASE` will fail if any other connection exists when it starts; otherwise, new connections to the template database are locked out until `CREATE DATABASE` completes.

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The character set encoding specified for the new database must be compatible with the chosen locale settings (`LC_COLLATE` and `LC_CTYPE`). If the locale is `C` (or equivalently `POSIX`), then all encodings are allowed, but for other locale settings there is only one encoding that will work properly. `CREATE DATABASE` will allow superusers to specify `SQL_ASCII` encoding regardless of the locale settings, but this choice is deprecated and may result in misbehavior of character-string functions if data that is not encoding-compatible with the locale is stored in the database.

The encoding and locale settings must match those of the template database, except when `template0` is used as template. This is because other databases might contain data that does not match the specified encoding, or might contain indexes whose ordering is affected by `LC_COLLATE` and `LC_CTYPE`. Copying such data would result in a database that is corrupt according to the new settings. `template0`, however, is known to not contain any data or indexes that would be affected.

The `CONNECTION LIMIT` option is enforced approximately; if two new sessions start at about the same time when just one connection "slot" remains for the database, it is possible that both will fail. Also, the limit is not enforced against superusers or background worker processes.

Examples

To create a new database:

```
CREATE DATABASE gpdb;
```

To create a database `sales` owned by user `salesapp` with a default tablespace of `salesspace`:

```
CREATE DATABASE sales OWNER salesapp TABLESPACE salesspace;
```

To create a database `music` with a different locale:

```
CREATE DATABASE music
    LC_COLLATE 'sv_SE.utf8' LC_CTYPE 'sv_SE.utf8'
    TEMPLATE template0;
```

In this example, the `TEMPLATE template0` clause is required if the specialized locale is different from the one in `template1`. (If it is not, then specifying the locale explicitly is redundant.)

To create a database `music2` with a different locale and a different character set encoding:

```
CREATE DATABASE music2
    LC_COLLATE 'sv_SE.iso885915' LC_CTYPE 'sv_SE.iso885915'
    ENCODING LATIN9
    TEMPLATE template0;
```

The specified locale and encoding settings must match, or an error will be reported.

Note that locale names are specific to the operating system, so that the above commands might not work in the same way everywhere.

Compatibility

There is no `CREATE DATABASE` statement in the SQL standard. Databases are equivalent to catalogs, whose creation is implementation-defined.

See Also

ALTER DATABASE, DROP DATABASE

Parent topic: SQL Commands

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7.1.56 CREATE DOMAIN

Defines a new domain.

Synopsis

```
CREATE DOMAIN <name> [AS] <data_type>
       [ COLLATE <collation> ]
       [ DEFAULT <expression> ]
       [ <constraint> [ ... ] ]

where <constraint> is:

[ CONSTRAINT <constraint_name> ]
{ NOT NULL | NULL | CHECK (<expression>)  }
```

Description

`CREATE DOMAIN` creates a new domain. A domain is essentially a data type with optional constraints (restrictions on the allowed set of values). The user who defines a domain becomes its owner.

If a schema name is given (for example, `CREATE DOMAIN myschema.mydomain ...`) then the domain is created in the specified schema. Otherwise it is created in the current schema. The domain name must be unique among the data types and domains existing in its schema.

Domains are useful for abstracting common constraints on fields into a single location for maintenance. For example, several tables might contain email address columns, all requiring the same `CHECK` constraint to verify the address syntax. Define a domain rather than setting up each table's constraint individually.

To be able to create a domain, you must have `USAGE` privilege on the underlying type.

Parameters

name The name (optionally schema-qualified) of a domain to be created.

data_type The underlying data type of the domain. This may include array specifiers.

collation An optional collation for the domain. If no collation is specified, the domain has the same collation behavior as its underlying data type. The underlying type must be collatable if `COLLATE` is specified.

DEFAULT expression Specifies a default value for columns of the domain data type. The value is any variable-free expression (but subqueries are not allowed). The data type of the default expression must match the data type of the domain. If no default value is specified, then the default value is the null value. The default expression will be used in any insert operation that does not specify a value for the column. If a default value is defined for a particular column, it overrides any default associated with the domain. In turn, the domain default overrides any default value associated with the underlying data type.

CONSTRAINT constraint_name An optional name for a constraint. If not specified, the system generates a name.

NOT NULL Values of this domain are prevented from being null (but see the Notes below).

NULL Values of this domain are allowed to be null. This is the default. This clause is only intended for compatibility with nonstandard SQL databases. Its use is discouraged in new applications.

CHECK (expression) `CHECK` clauses specify integrity constraints or tests which values of the domain must satisfy. Each constraint must be an expression producing a Boolean result. It should use the key word `VALUE` to refer to the value being tested. Expressions evaluating to TRUE or UNKNOWN succeed. If the expression produces a FALSE result, an error is reported and the value is not allowed to be converted to the domain type. Currently, `CHECK` expressions cannot contain subqueries nor refer to variables other than `VALUE`. When a domain has multiple `CHECK` constraints, they will be tested in alphabetical order by name. (WarehousePG versions before 7.0 did not honor any particular firing order for `CHECK` constraints.)

Notes

Domain constraints, particularly `NOT NULL`, are checked when converting a value to the domain type. It is possible for a column that is nominally of the domain type to read as null despite there being such a constraint. For example, this can happen in an outer-join query, if the domain column is on the nullable side of the outer join. A more subtle example is:

```
INSERT INTO tab (domcol) VALUES ((SELECT domcol FROM tab WHERE false));
```

The empty scalar sub-SELECT will produce a null value that is considered to be of the domain type, so no further constraint checking is applied to it, and the insertion will succeed.

It is very difficult to avoid such problems, because of SQL's general assumption that a null value is a valid value of every data type. Best practice therefore is to design a domain's constraints so that a null value is allowed, and then to apply column `NOT NULL` constraints to columns of the domain type as needed, rather than directly to the domain type.

Greeplum Database assumes that `CHECK` constraints' conditions are immutable, that is, they will always give the same result for the same input value. This assumption is what justifies examining `CHECK` constraints only when a value is first converted to be of a domain type, and not at other times. (This is essentially the same as the treatment of table `CHECK` constraints.)

An example of a common way to break this assumption is to reference a user-defined function in a `CHECK` expression, and then change the behavior of that function. WarehousePG does not disallow that, but it will not notice if there are stored values of the domain type that now violate the `CHECK` constraint. That would cause a subsequent database dump and restore to fail. The recommended way to handle such a change is to drop the constraint (using `ALTER DOMAIN`), adjust the function definition, and re-add the constraint, thereby rechecking it against stored data.

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Examples

This example creates the `us_postal_code` data type and then uses the type in a table definition. A regular expression test is used to verify that the value looks like a valid US postal code.

```
CREATE DOMAIN us_postal_code AS TEXT
CHECK(
   VALUE ~ '^\d{5}$'
OR VALUE ~ '^\d{5}-\d{4}$'
);

CREATE TABLE us_snail_addy (
  address_id SERIAL PRIMARY KEY,
  street1 TEXT NOT NULL,
  street2 TEXT,
  street3 TEXT,
  city TEXT NOT NULL,
  postal us_postal_code NOT NULL
);
```

Compatibility

`CREATE DOMAIN` conforms to the SQL standard.

See Also

ALTER DOMAIN, DROP DOMAIN

Parent topic: SQL Commands

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7.1.57 CREATE EXTENSION

Registers an extension in a WarehousePG.

Synopsis

```
CREATE EXTENSION [ IF NOT EXISTS ] <extension_name>
  [ WITH ] [ SCHEMA <schema_name> ]
           [ VERSION <version> ]
           [ FROM <old_version> ]
           [ CASCADE ]
```

Description

`CREATE EXTENSION` loads a new extension into the current database. There must not be an extension of the same name already loaded.

Loading an extension essentially amounts to running the extension script file. The script typically creates new SQL objects such as functions, data types, operators, and index support methods. `CREATE EXTENSION` additionally records the identities of all of the created objects, so that they can be dropped again if `DROP EXTENSION` is issued.

Loading an extension requires the same privileges that would be required to create its component objects. For most extensions this means superuser or database owner privileges are required. The user who runs `CREATE EXTENSION` becomes the owner of the extension for purposes of later privilege checks, as well as the owner of any objects created by the extension script.

Parameters

IF NOT EXISTS Do not throw an error if an extension with the same name already exists. WarehousePG issues a notice in this case. Note that there is no guarantee that the existing extension is anything like the one that would have been created from the currently-available script file.

extension_name The name of the extension to be installed. WarehousePG will create the extension using details from the file `SHAREDIR/extension/<extension_name>.control`. `SHAREDIR` is the installation shared-data directory, for example `/usr/edb/whpg7/share/postgresql`. The command `pg_config --sharedir` displays the directory.

schema_name The name of the schema in which to install the extension objects, given that the extension allows its contents to be relocated. The named schema must already exist. If not specified, and the extension's control file does not specify a schema either, the current default object creation schema is used. If the extension specifies a schema parameter in its control file, then that schema cannot be overridden with a `SCHEMA` clause. Normally, an error is raised if a `SCHEMA` clause is given and it conflicts with the extension's `schema` parameter. However, if the `CASCADE` clause is also given, then schema_name is ignored when it conflicts. The given schema_name is used for installation of any needed extensions that do not a specify schema in their control files. Remember that the extension itself is not considered to be within any schema: extensions have unqualified names that must be unique database-wide. But objects belonging to the extension can be within schemas.

version The version of the extension to install. This can be written as either an identifier or a string literal. The default version is whatever is specified in the extension's control file.

old_version Specify `FROM old_version` only if you are attempting to install an extension that replaces an *old-style* module that is a collection of objects that is not packaged into an extension. This option causes `CREATE EXTENSION` to run an alternative installation script that absorbs the existing objects into the extension, instead of creating new objects. Ensure that `SCHEMA` specifies the schema containing these pre-existing objects. The value to use for old_version is determined by the extension's author, and might vary if there is more than one version of the old-style module that can be upgraded into an extension.

CASCADE Automatically install any extensions that this extension depends on that are not already installed. Dependent extensions are checked recursively and those dependencies are also installed automatically. If the `SCHEMA` clause is specified, the schema applies to the extension and all dependent extensions that are installed. Other options that are specified are not applied to the automatically-installed dependent extensions; in particular, their default versions are always selected.

Notes

Before you can use `CREATE EXTENSION` to load an extension into a database, the extension's supporting files must be installed. The supporting files must be installed in the same location on all WarehousePG hosts. For information about creating new extensions, see the PostgreSQL Packaging Related Objects into an Extension documentation.

The extensions currently available for loading can be identified from the pg_available_extensions or pg_available_extension_versions system views.

> **Note:** Installing an extension as superuser requires trusting that the extension's author wrote the extension installation script in a secure fashion. It is not terribly difficult for a malicious user to create trojan-horse objects that will compromise later execution of a carelessly-written extension script, allowing that user to acquire superuser privileges. However, trojan-horse objects are only hazardous if they are in the `search_path` during script execution, meaning that they are in the extension's installation target schema or in the schema of some extension it depends on. Therefore, a good rule of thumb when dealing with extensions whose scripts have not been carefully vetted is to install them only into schemas for which `CREATE` privilege has not been and will not be granted to any untrusted users. Likewise for any extensions they depend on.
>
> The extensions supplied with WarehousePG are believed to be secure against installation-time attacks of this sort, except for a few that depend on other extensions. As stated in the documentation for those extensions, they should be installed into secure schemas, or installed into the same schemas as the extensions they depend on, or both.

Examples

Install the `hstore` extension into the current database, placing its objects in schema `addons`:

```
CREATE EXTENSION hstore SCHEMA addons;
```

Another way to accomplish the same thing:

```
SET search_path = addons;
CREATE EXTENSION hstore;
```

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Compatibility

`CREATE EXTENSION` is a WarehousePG extension.

See Also

ALTER EXTENSION, DROP EXTENSION

Parent topic: SQL Commands

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7.1.58 CREATE EXTERNAL TABLE

Defines a new external table.

Synopsis

```
CREATE [READABLE] EXTERNAL [TEMPORARY | TEMP] TABLE <table_name>
    ( <column_name> <data_type> [, ...] | LIKE <other_table >)
     LOCATION ('file://<seghost>[:<port>]/<path>/<file>' [, ...])
       | ('gpfdist://<filehost>[:<port>]/<file_pattern>[#transform=<trans_name>]'
           [, ...]
       | ('gpfdists://<filehost>[:<port>]/<file_pattern>[#transform=<trans_name>]'
           [, ...])
       | ('pxf://<path-to-data>?PROFILE=<profile_name>[&SERVER=<server_name>][&<custom-option>=<value>[...]]'))
       | ('s3://<S3_endpoint>[:<port>]/<bucket_name>/[<S3_prefix>] [region=<S3-region>] [config=<config_file> | config_server=<url>]')
     [ON COORDINATOR]
     FORMAT 'TEXT'
          [( [HEADER]
             [DELIMITER [AS] '<delimiter>' | 'OFF']
             [NULL [AS] '<null string>']
             [ESCAPE [AS] '<escape>' | 'OFF']
             [NEWLINE [ AS ] 'LF' | 'CR' | 'CRLF']
             [FILL MISSING FIELDS] )]
         | 'CSV'
          [( [HEADER]
             [QUOTE [AS] '<quote>']
             [DELIMITER [AS] '<delimiter>']
             [NULL [AS] '<null string>']
             [FORCE NOT NULL <column> [, ...]]
             [ESCAPE [AS] '<escape>']
             [NEWLINE [ AS ] 'LF' | 'CR' | 'CRLF']
             [FILL MISSING FIELDS] )]
         | 'CUSTOM' (Formatter=<<formatter_specifications>>)
    [ OPTIONS ( <key> '<value>' [, ...] ) ]
    [ ENCODING '<encoding>' ]
      [ [LOG ERRORS [PERSISTENTLY]] SEGMENT REJECT LIMIT <count>
      [ROWS | PERCENT] ]

CREATE [READABLE] EXTERNAL WEB [TEMPORARY | TEMP] TABLE <table_name>
   ( <column_name> <data_type> [, ...] | LIKE <other_table >)
      LOCATION ('http://<webhost>[:<port>]/<path>/<file>' [, ...])
    | EXECUTE '<command>' [ON ALL
                          | COORDINATOR
                          | <number_of_segments>
                          | HOST ['<segment_hostname>']
                          | SEGMENT <segment_id> ]
      FORMAT 'TEXT'
           [( [HEADER]
              [DELIMITER [AS] '<delimiter>' | 'OFF']
              [NULL [AS] '<null string>']
              [ESCAPE [AS] '<escape>' | 'OFF']
              [NEWLINE [ AS ] 'LF' | 'CR' | 'CRLF']
              [FILL MISSING FIELDS] )]
          | 'CSV'
           [( [HEADER]
              [QUOTE [AS] '<quote>']
              [DELIMITER [AS] '<delimiter>']
              [NULL [AS] '<null string>']
              [FORCE NOT NULL <column> [, ...]]
              [ESCAPE [AS] '<escape>']
              [NEWLINE [ AS ] 'LF' | 'CR' | 'CRLF']
              [FILL MISSING FIELDS] )]
          | 'CUSTOM' (Formatter=<<formatter specifications>>)
     [ OPTIONS ( <key> '<value>' [, ...] ) ]
     [ ENCODING '<encoding>' ]
     [ [LOG ERRORS [PERSISTENTLY]] SEGMENT REJECT LIMIT <count>
       [ROWS | PERCENT] ]

CREATE WRITABLE EXTERNAL [TEMPORARY | TEMP] TABLE <table_name>
    ( <column_name> <data_type> [, ...] | LIKE <other_table >)
     LOCATION('gpfdist://<outputhost>[:<port>]/<filename>[#transform=<trans_name>]'
          [, ...])
      | ('gpfdists://<outputhost>[:<port>]/<file_pattern>[#transform=<trans_name>]'
          [, ...])
      FORMAT 'TEXT'
               [( [DELIMITER [AS] '<delimiter>']
               [NULL [AS] '<null string>']
               [ESCAPE [AS] '<escape>' | 'OFF'] )]
          | 'CSV'
               [([QUOTE [AS] '<quote>']
               [DELIMITER [AS] '<delimiter>']
               [NULL [AS] '<null string>']
               [FORCE QUOTE <column> [, ...]] | * ]
               [ESCAPE [AS] '<escape>'] )]

          | 'CUSTOM' (Formatter=<<formatter specifications>>)
    [ OPTIONS ( <key> '<value>' [, ...] ) ]
    [ ENCODING '<write_encoding>' ]
    [ DISTRIBUTED BY ({<column> [<opclass>]}, [ ... ] ) | DISTRIBUTED RANDOMLY ]
```

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```
CREATE WRITABLE EXTERNAL [TEMPORARY | TEMP] TABLE <table_name>
    ( <column_name> <data_type> [, ...] | LIKE <other_table >)
     LOCATION('s3://<S3_endpoint>[:<port>]/<bucket_name>/[<S3_prefix>] [region=<S3-region>] [config=<config_file> | config_server=<url>]')
      [ON COORDINATOR]
      FORMAT 'TEXT'
               [( [DELIMITER [AS] '<delimiter>']
               [NULL [AS] '<null string>']
               [ESCAPE [AS] '<escape>' | 'OFF'] )]
          | 'CSV'
               [([QUOTE [AS] '<quote>']
               [DELIMITER [AS] '<delimiter>']
               [NULL [AS] '<null string>']
               [FORCE QUOTE <column> [, ...]] | * ]
               [ESCAPE [AS] '<escape>'] )]

CREATE WRITABLE EXTERNAL WEB [TEMPORARY | TEMP] TABLE <table_name>
    ( <column_name> <data_type> [, ...] | LIKE <other_table> )
    EXECUTE '<command>' [ON ALL]
    FORMAT 'TEXT'
               [( [DELIMITER [AS] '<delimiter>']
               [NULL [AS] '<null string>']
               [ESCAPE [AS] '<escape>' | 'OFF'] )]
          | 'CSV'
               [([QUOTE [AS] '<quote>']
               [DELIMITER [AS] '<delimiter>']
               [NULL [AS] '<null string>']
               [FORCE QUOTE <column> [, ...]] | * ]
               [ESCAPE [AS] '<escape>'] )]
           | 'CUSTOM' (Formatter=<<formatter specifications>>)
    [ OPTIONS ( <key> '<value>' [, ...] ) ]
    [ ENCODING '<write_encoding>' ]
    [ DISTRIBUTED BY ({<column> [<opclass>]}, [ ... ] ) | DISTRIBUTED RANDOMLY ]
```

Description

`CREATE EXTERNAL TABLE` or `CREATE EXTERNAL WEB TABLE` creates a new readable external table definition in WarehousePG. Readable external tables are typically used for fast, parallel data loading. Once an external table is defined, you can query its data directly (and in parallel) using SQL commands. For example, you can select, join, or sort external table data. You can also create views for external tables. DML operations (`UPDATE`, `INSERT`, `DELETE`, or `TRUNCATE`) are not allowed on readable external tables, and you cannot create indexes on readable external tables.

`CREATE WRITABLE EXTERNAL TABLE` or `CREATE WRITABLE EXTERNAL WEB TABLE` creates a new writable external table definition in WarehousePG. Writable external tables are typically used for unloading data from the database into a set of files or named pipes. Writable external web tables can also be used to output data to an executable program. Once a writable external table is defined, data can be selected from database tables and inserted into the writable external table. Writable external tables only allow `INSERT` operations – `SELECT`, `UPDATE`, `DELETE` or `TRUNCATE` are not allowed.

The main difference between regular external tables and external web tables is their data sources. Regular readable external tables access static flat files, whereas external web tables access dynamic data sources – either on a web server or by running OS commands or scripts.

See Working with External Data for detailed information about working with external tables.

Parameters

READABLE | WRITABLE

Specifies the type of external table, readable being the default. Readable external tables are used for loading data into WarehousePG. Writable external tables are used for unloading data.

WEB

Creates a readable or writable external web table definition in WarehousePG. There are two forms of readable external web tables – those that access files via the `http://` protocol or those that access data by running OS commands. Writable external web tables output data to an executable program that can accept an input stream of data. External web tables are not rescannable during query execution.

The `s3` protocol does not support external web tables. You can, however, create an external web table that runs a third-party tool to read data from or write data to S3 directly.

TEMPORARY | TEMP

If specified, creates a temporary readable or writable external table definition in WarehousePG. Temporary external tables exist in a special schema; you cannot specify a schema name when you create the table. Temporary external tables are automatically dropped at the end of a session.

An existing permanent table with the same name is not visible to the current session while the temporary table exists, unless you reference the permanent table with its schema-qualified name.

table_name

The name of the new external table.

column_name

The name of a column to create in the external table definition. Unlike regular tables, external tables do not have column constraints or default values, so do not specify those.

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LIKE other_table

The `LIKE` clause specifies a table from which the new external table automatically copies all column names, data types and WarehousePG distribution policy. If the original table specifies any column constraints or default column values, those will not be copied over to the new external table definition.

data_type

The data type of the column.

LOCATION ('protocol://[host[:port]]/path/file' [, ...])

If you use the `pxf` protocol to access an external data source, refer to pxf:// Protocol for information about the `pxf` protocol.

If you use the `s3` protocol to read or write to S3, refer to s3:// Protocol for additional information about the `s3` protocol `LOCATION` clause syntax.

For readable external tables, specifies the URI of the external data source(s) to be used to populate the external table or web table. Regular readable external tables allow the `gpfdist` or `file` protocols. External web tables allow the `http` protocol. If `port` is omitted, port `8080` is assumed for `http` and `gpfdist` protocols. If using the `gpfdist` protocol, the `path` is relative to the directory from which `gpfdist` is serving files (the directory specified when you started the `gpfdist` program). Also, `gpfdist` can use wildcards or other C-style pattern matching (for example, a whitespace character is `[[:space:]]`) to denote multiple files in a directory. For example:

```
'gpfdist://filehost:8081/*'
'gpfdist://coordinatorhost/my_load_file'
'file://seghost1/dbfast1/external/myfile.txt'
'http://intranet.example.com/finance/expenses.csv'
```

For writable external tables, specifies the URI location of the `gpfdist` process or S3 protocol that will collect data output from the WarehousePG segments and write it to one or more named files. For `gpfdist` the `path` is relative to the directory from which `gpfdist` is serving files (the directory specified when you started the `gpfdist` program). If multiple `gpfdist` locations are listed, the segments sending data will be evenly divided across the available output locations. For example:

```
'gpfdist://outputhost:8081/data1.out',
'gpfdist://outputhost:8081/data2.out'
```

With two `gpfdist` locations listed as in the above example, half of the segments would send their output data to the `data1.out` file and the other half to the `data2.out` file.

With the option `#transform=trans_name`, you can specify a transform to apply when loading or extracting data. The trans_name is the name of the transform in the YAML configuration file you specify with the you run the `gpfdist` utility. For information about specifying a transform, see gpfdist in the *WarehousePG Utility Guide*.

ON COORDINATOR

Restricts all table-related operations to the WarehousePG coordinator segment. Permitted only on readable and writable external tables created with the `s3` or custom protocols. The `gpfdist`, `gpfdists`, `pxf`, and `file` protocols do not support `ON COORDINATOR`.

> **Note**
>
> Be aware of potential resource impacts when reading from or writing to external tables you create with the `ON COORDINATOR` clause. You may encounter performance issues when you restrict table operations solely to the WarehousePG coordinator segment.

EXECUTE 'command' [ON ...]

Allowed for readable external web tables or writable external tables only. For readable external web tables, specifies the OS command to be run by the segment instances. The command can be a single OS command or a script. The `ON` clause is used to specify which segment instances will run the given command.

- ON ALL is the default. The command will be run by every active (primary) segment instance on all segment hosts in the WarehousePG cluster. If the command runs a script, that script must reside in the same location on all of the segment hosts and be executable by the WarehousePG superuser (`gpadmin`).
- ON COORDINATOR runs the command on the coordinator host only.

  > **Note**
  >
  > Logging is not supported for external web tables when the `ON COORDINATOR` clause is specified.

- ON number means the command will be run by the specified number of segments. The particular segments are chosen randomly at runtime by the WarehousePG cluster. If the command runs a script, that script must reside in the same location on all of the segment hosts and be executable by the WarehousePG superuser (`gpadmin`).
- HOST means the command will be run by one segment on each segment host (once per segment host), regardless of the number of active segment instances per host.
- HOST segment_hostname means the command will be run by all active (primary) segment instances on the specified segment host.
- SEGMENT segment_id means the command will be run only once by the specified segment. You can determine a segment instance's ID by looking at the content number in the system catalog tablegp_segment_configuration. The content ID of the WarehousePG coordinator is always `-1`.

For writable external tables, the command specified in the `EXECUTE` clause must be prepared to have data piped into it. Since all segments that have data to send will write their output to the specified command or program, the only available option for the `ON` clause is `ON ALL`.

FORMAT 'TEXT | CSV' (options)

When the `FORMAT` clause identfies delimited text (`TEXT`) or comma separated values (`CSV`) format, formatting options are similar to those available with the PostgreSQL COPY command. If the data in the file does not use the default column delimiter, escape character, null string and so on, you must specify the additional formatting options so that the data in the external file is read correctly by WarehousePG. For information about using a custom format, see Loading and Unloading Data in the *WarehousePG Administrator Guide*.

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If you use the `pxf` protocol to access an external data source, refer to Accessing External Data with PXF for information about using PXF.

FORMAT 'CUSTOM' (formatter=formatter_specification)

Specifies a custom data format. The formatter_specification specifies the function to use to format the data, followed by comma-separated parameters to the formatter function. The length of the formatter specification, the string including `Formatter=`, can be up to approximately 50K bytes.

If you use the `pxf` protocol to access an external data source, refer to Accessing External Data with PXF for information about using PXF.

For general information about using a custom format, see "Loading and Unloading Data" in the *WarehousePG Administrator Guide*.

DELIMITER

Specifies a single ASCII character that separates columns within each row (line) of data. The default is a tab character in `TEXT` mode, a comma in `CSV` mode. In `TEXT` mode for readable external tables, the delimiter can be set to `OFF` for special use cases in which unstructured data is loaded into a single-column table.

For the `s3` protocol, the delimiter cannot be a newline character (`\n`) or a carriage return character (`\r`).

NULL

Specifies the string that represents a `NULL` value. The default is `\N` (backslash-N) in `TEXT` mode, and an empty value with no quotations in `CSV` mode. You might prefer an empty string even in `TEXT` mode for cases where you do not want to distinguish `NULL` values from empty strings. When using external and web tables, any data item that matches this string will be considered a `NULL` value.

As an example for the `text` format, this `FORMAT` clause can be used to specify that the string of two single quotes (`''`) is a `NULL` value.

```
FORMAT 'text' (delimiter ',' null '\'\'\'\'' )
```

ESCAPE

Specifies the single character that is used for C escape sequences (such as `\n`, `\t`, `\100`, and so on) and for escaping data characters that might otherwise be taken as row or column delimiters. Make sure to choose an escape character that is not used anywhere in your actual column data. The default escape character is a `\` (backslash) for text-formatted files and a `"` (double quote) for csv-formatted files, however it is possible to specify another character to represent an escape. It is also possible to deactivate escaping in text-formatted files by specifying the value `'OFF'` as the escape value. This is very useful for data such as text-formatted web log data that has many embedded backslashes that are not intended to be escapes.

NEWLINE

Specifies the newline used in your data files – `LF` (Line feed, 0x0A), `CR` (Carriage return, 0x0D), or `CRLF` (Carriage return plus line feed, 0x0D 0x0A). If not specified, a WarehousePG segment will detect the newline type by looking at the first row of data it receives and using the first newline type encountered.

HEADER

For readable external tables, specifies that the first line in the data file(s) is a header row (contains the names of the table columns) and should not be included as data for the table. If using multiple data source files, all files must have a header row.

For the `s3` protocol, the column names in the header row cannot contain a newline character (`\n`) or a carriage return (`\r`).

The `pxf` protocol does not support the `HEADER` formatting option.

QUOTE

Specifies the quotation character for `CSV` mode. The default is double-quote (`"`).

FORCE NOT NULL

In `CSV` mode, processes each specified column as though it were quoted and hence not a `NULL` value. For the default null string in `CSV` mode (nothing between two delimiters), this causes missing values to be evaluated as zero-length strings.

FORCE QUOTE

In `CSV` mode for writable external tables, forces quoting to be used for all non-`NULL` values in each specified column. If `*` is specified then non-`NULL` values will be quoted in all columns. `NULL` output is never quoted.

FILL MISSING FIELDS

In both `TEXT` and `CSV` mode for readable external tables, specifying `FILL MISSING FIELDS` will set missing trailing field values to `NULL` (instead of reporting an error) when a row of data has missing data fields at the end of a line or row. Blank rows, fields with a `NOT NULL` constraint, and trailing delimiters on a line will still report an error.

OPTIONS key 'value'[, key' value' ...]

Optional. Specifies parameters and values as key-value pairs that are set to a custom data access protocol when the protocol is used as a external table protocol for an external table. It is the responsibility of the custom data access protocol to process and validate the key-value pairs.

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ENCODING 'encoding'

Character set encoding to use for the external table. Specify a string constant (such as `'SQL_ASCII'`), an integer encoding number, or `DEFAULT` to use the default server encoding. See Character Set Support.

LOG ERRORS [PERSISTENTLY]

This is an optional clause that can precede a `SEGMENT REJECT LIMIT` clause to log information about rows with formatting errors. The error log data is stored internally. If error log data exists for a specified external table, new data is appended to existing error log data. The error log data is not replicated to mirror segments.

The data is deleted when the external table is dropped unless you specify the keyword `PERSISTENTLY`. If the keyword is specified, the log data persists after the external table is dropped.

The error log data is accessed with the WarehousePG built-in SQL function `gp_read_error_log()`, or with the SQL function `gp_read_persistent_error_log()` if the `PERSISTENTLY` keyword is specified.

If you use the `PERSISTENTLY` keyword, you must install the functions that manage the persistent error log information.

See Notes for information about the error log information and built-in functions for viewing and managing error log information.

SEGMENT REJECT LIMIT count [ROWS | PERCENT]

Runs a `COPY FROM` operation in single row error isolation mode. If the input rows have format errors they will be discarded provided that the reject limit count is not reached on any WarehousePG segment instance during the load operation. The reject limit count can be specified as number of rows (the default) or percentage of total rows (1-100). If `PERCENT` is used, each segment starts calculating the bad row percentage only after the number of rows specified by the parameter `gp_reject_percent_threshold` has been processed. The default for `gp_reject_percent_threshold` is 300 rows. Constraint errors such as violation of a `NOT NULL`, `CHECK`, or `UNIQUE` constraint will still be handled in "all-or-nothing" input mode. If the limit is not reached, all good rows will be loaded and any error rows discarded.

> **Note**
>
> When reading an external table, WarehousePG limits the initial number of rows that can contain formatting errors if the `SEGMENT REJECT LIMIT` is not triggered first or is not specified. If the first 1000 rows are rejected, the `COPY` operation is stopped and rolled back.

You can change the limit for the number of initial rejected rows with the WarehousePG server configuration parameter gp_initial_bad_row_limit.

```
DISTRIBUTED BY \(\{column \[opclass\]\}, \[ ... \] \)
DISTRIBUTED RANDOMLY
```

Used to declare the WarehousePG distribution policy for a writable external table. By default, writable external tables are distributed randomly. If the source table you are exporting data from has a hash distribution policy, defining the same distribution key column(s) and operator class(es), `oplcass`, for the writable external table will improve unload performance by eliminating the need to move rows over the interconnect. When you issue an unload command such as `INSERT INTO wex_table SELECT * FROM source_table`, the rows that are unloaded can be sent directly from the segments to the output location if the two tables have the same hash distribution policy.

Examples

Start the `gpfdist` file server program in the background on port `8081` serving files from directory `/var/data/staging`:

```
gpfdist -p 8081 -d /var/data/staging -l /home/<gpadmin>/log &
```

Create a readable external table named `ext_customer` using the `gpfdist` protocol and any text formatted files (`*.txt`) found in the `gpfdist` directory. The files are formatted with a pipe (`|`) as the column delimiter and an empty space as `NULL`. Also access the external table in single row error isolation mode:

```
CREATE EXTERNAL TABLE ext_customer
   (id int, name text, sponsor text)
   LOCATION ( 'gpfdist://filehost:8081/*.txt' )
   FORMAT 'TEXT' ( DELIMITER '|' NULL ' ')
   LOG ERRORS SEGMENT REJECT LIMIT 5;
```

Create the same readable external table definition as above, but with CSV formatted files:

```
CREATE EXTERNAL TABLE ext_customer
   (id int, name text, sponsor text)
   LOCATION ( 'gpfdist://filehost:8081/*.csv' )
   FORMAT 'CSV' ( DELIMITER ',' );
```

Create a readable external table named `ext_expenses` using the `file` protocol and several CSV formatted files that have a header row:

```
CREATE EXTERNAL TABLE ext_expenses (name text, date date,
amount float4, category text, description text)
LOCATION (
'file://seghost1/dbfast/external/expenses1.csv',
'file://seghost1/dbfast/external/expenses2.csv',
'file://seghost2/dbfast/external/expenses3.csv',
'file://seghost2/dbfast/external/expenses4.csv',
'file://seghost3/dbfast/external/expenses5.csv',
'file://seghost3/dbfast/external/expenses6.csv'
)
FORMAT 'CSV' ( HEADER );
```

Create a readable external web table that runs a script once per segment host:

```
CREATE EXTERNAL WEB TABLE log_output (linenum int, message
text)  EXECUTE '/var/load_scripts/get_log_data.sh' ON HOST
 FORMAT 'TEXT' (DELIMITER '|');
```

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Create a writable external table named `sales_out` that uses `gpfdist` to write output data to a file named `sales.out`. The files are formatted with a pipe (`|`) as the column delimiter and an empty space as `NULL`.

```
CREATE WRITABLE EXTERNAL TABLE sales_out (LIKE sales)
   LOCATION ('gpfdist://etl1:8081/sales.out')
   FORMAT 'TEXT' ( DELIMITER '|' NULL ' ')
   DISTRIBUTED BY (txn_id);
```

Create a writable external web table that pipes output data received by the segments to an executable script named `to_adreport_etl.sh`:

```
CREATE WRITABLE EXTERNAL WEB TABLE campaign_out
(LIKE campaign)
 EXECUTE '/var/unload_scripts/to_adreport_etl.sh'
 FORMAT 'TEXT' (DELIMITER '|');
```

Use the writable external table defined above to unload selected data:

```
INSERT INTO campaign_out SELECT * FROM campaign WHERE customer_id=123;
```

Notes

When you specify the `LOG ERRORS` clause, WarehousePG captures errors that occur while reading the external table data. For information about the error log format, see Viewing Bad Rows in the Error Log.

You can view and manage the captured error log data. The functions to manage log data depend on whether the data is persistent (the `PERSISTENTLY` keyword is used with the `LOG ERRORS` clause).

- Functions that manage non-persistent error log data from external tables that were defined without the `PERSISTENTLY` keyword.
    - The built-in SQL function `gp_read_error_log('table_name')` displays error log information for an external table. This example displays the error log data from the external table `ext_expenses`.

      ```
      SELECT * from gp_read_error_log('ext_expenses');
      ```

      The function returns no data if you created the external table with the `LOG ERRORS PERSISTENTLY` clause, or if the external table does not exist.
    - The built-in SQL function `gp_truncate_error_log('table_name')` deletes the error log data for table_name. This example deletes the error log data captured from the external table `ext_expenses`:

      ```
      SELECT gp_truncate_error_log('ext_expenses');
      ```

      Dropping the table also deletes the table's log data. The function does not truncate log data if the external table is defined with the `LOG ERRORS PERSISTENTLY` clause.

      The function returns `FALSE` if the table does not exist.
- Functions that manage persistent error log data from external tables that were defined with the `PERSISTENTLY` keyword.
    - The SQL function `gp_read_persistent_error_log('table_name')` displays persistent log data for an external table.

      The function returns no data if you created the external table without the `PERSISTENTLY` keyword. The function returns persistent log data for an external table even after the table has been dropped.
    - The SQL function `gp_truncate_persistent_error_log('table_name')` truncates persistent log data for a table.

      For persistent log data, you must manually delete the data. Dropping the external table does not delete persistent log data.
- These items apply to both non-persistent and persistent error log data and the related functions.
    - The `gp_read_*` functions require `SELECT` privilege on the table.
    - The `gp_truncate_*` functions require owner privilege on the table.
    - You can use the `*` wildcard character to delete error log information for existing tables in the current database. Specify the string `*.*` to delete all database error log information, including error log information that was not deleted due to previous database issues. If `*` is specified, database owner privilege is required. If `*.*` is specified, operating system super-user privilege is required. Non-persistent and persistent error log data must be deleted with their respective `gp_truncate_*` functions.

When multiple WarehousePG external tables are defined with the `gpfdist`, `gpfdists`, or `file` protocol and access the same named pipe a Linux system, WarehousePG restricts access to the named pipe to a single reader. An error is returned if a second reader attempts to access the named pipe.

Compatibility

`CREATE EXTERNAL TABLE` is a WarehousePG extension. The SQL standard makes no provisions for external tables.

See Also

CREATE TABLE AS, CREATE TABLE, COPY, SELECT INTO, INSERT

Parent topic: SQL Commands

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7.1.59 CREATE FOREIGN DATA WRAPPER

Defines a new foreign-data wrapper.

Synopsis

```
CREATE FOREIGN DATA WRAPPER <name>
    [ HANDLER <handler_function> | NO HANDLER ]
    [ VALIDATOR <validator_function> | NO VALIDATOR ]
    [ OPTIONS ( [ mpp_execute { 'coordinator' | 'any' | 'all segments' } [, ] ] <option> '<value>' [, ... ] ) ]
```

Description

`CREATE FOREIGN DATA WRAPPER` creates a new foreign-data wrapper in the current database. The user who defines the foreign-data wrapper becomes its owner.

The foreign-data wrapper name must be unique within the database.

Only superusers can create foreign-data wrappers.

Parameters

name The name of the foreign-data wrapper to create. The name must be unique within the database.

HANDLER handler_function The name of a previously registered function that WarehousePG calls to retrieve the execution functions for foreign tables. hander_function must take no arguments, and its return type must be `fdw_handler`. It is possible to create a foreign-data wrapper with no handler function, but you can only declare, not access, foreign tables using such a wrapper.

VALIDATOR validator_function The name of a previously registered function that WarehousePG calls to check the generic options provided to the foreign-data wrapper. This function also checks the options for foreign servers, user mappings, and foreign tables that use the foreign-data wrapper. If no validator function or `NO VALIDATOR` is specified, WarehousePG does not check options at creation time. (Depending upon the implementation, foreign-data wrappers may ignore or reject invalid options at runtime.) validator_function must take two arguments: one of type `text[]`, which contains the array of options as stored in the system catalogs, and one of type `oid`, which identifies the OID of the system catalog containing the options. The return type is ignored; validator_function should report invalid options using the `ereport(ERROR)` function.

OPTIONS (option 'value' [, ...]) The options for the new foreign-data wrapper. Option names must be unique. The option names and values are foreign-data wrapper-specific and are validated using the foreign-data wrappers' validator_function.

mpp_execute { 'coordinator' | 'any' | 'all segments' } A WarehousePG-specific option that identifies the host from which the foreign-data wrapper reads or writes data:

```
-   `coordinator` \(the default\)—Read or write data from the coordinator host.
-   `any`—Read data from either the coordinator host or any one segment, depending on which path costs less.
-   `all segments`—Read or write data from all segments. To support this option value, the foreign-data wrapper must have a policy that matches the segments to
data.

> **Note** WarehousePG supports parallel writes to foreign tables only when you set `mpp_execute 'all segments'`.

Support for the foreign-data wrapper `mpp_execute` option, and the specific modes, is foreign-data wrapper-specific.

The `mpp_execute` option can be specified in multiple commands: `CREATE FOREIGN TABLE`, `CREATE SERVER`, and `CREATE FOREIGN DATA WRAPPER`. The foreign table
setting takes precedence over the foreign server setting, followed by the foreign-data wrapper setting.
```

Notes

The foreign-data wrapper functionality is still under development. Optimization of queries is primitive (and mostly left to the wrapper).

Examples

Create a useless foreign-data wrapper named `dummy`:

```
CREATE FOREIGN DATA WRAPPER dummy;
```

Create a foreign-data wrapper named `file` with a handler function named `file_fdw_handler`:

```
CREATE FOREIGN DATA WRAPPER file HANDLER file_fdw_handler;
```

Create a foreign-data wrapper named `mywrapper` that includes an option:

```
CREATE FOREIGN DATA WRAPPER mywrapper OPTIONS (debug 'true');
```

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Compatibility

`CREATE FOREIGN DATA WRAPPER` conforms to ISO/IEC 9075-9 (SQL/MED), with the exception that the `HANDLER` and `VALIDATOR` clauses are extensions, and the standard clauses `LIBRARY` and `LANGUAGE` are not implemented in WarehousePG.

Note, however, that the SQL/MED functionality as a whole is not yet conforming.

See Also

ALTER FOREIGN DATA WRAPPER, DROP FOREIGN DATA WRAPPER, CREATE FOREIGN TABLE, CREATE SERVER, CREATE USER MAPPING

Parent topic: SQL Commands

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7.1.60 CREATE FOREIGN TABLE

Defines a new foreign table.

Synopsis

```
CREATE FOREIGN TABLE [ IF NOT EXISTS ] <table_name> ( [
  { <column_name> <data_type> [ OPTIONS ( <option> '<value>' [, ... ] ) ] [ COLLATE <collation> ] [ <column_constraint> [ ... ] ]
    | <table_constraint> }
    [, ... ]
] )
[ INHERITS ( <parent_table> [, ... ] ) ]
  SERVER <server_name>
  [ OPTIONS ( [ mpp_execute { 'coordinator' | 'any' | 'all segments' } [, ] ] <option> '<value>' [, ... ] ) ]

CREATE FOREIGN TABLE [ IF NOT EXISTS ] <table_name>
  PARTITION OF <parent_table> [ (
  { <column_name> [ WITH OPTIONS ] [ <column_constraint> [ ... ] ]
    | <table_constraint> }
    [, ... ]
) ]
{ FOR VALUES <partition_bound_spec> | DEFAULT }
  SERVER <server_name>
  [ OPTIONS ( [ mpp_execute { 'coordinator' | 'any' | 'all segments' } [, ] ] <option> '<value>' [, ... ] ) ]

where <column_constraint> is:

[ CONSTRAINT <constraint_name> ]
{ NOT NULL |
  NULL |
  DEFAULT <default_expr> |
  GENERATED ALWAYS AS ( <generation_expr> ) STORED}

and <table_constraint> is:

[ CONSTRAINT <constraint_name> ]
CHECK ( <expression> ) [ NO INHERIT ]

and <partition_bound_spec> is:

IN ( <partition_bound_expr> [, ...] ) |
FROM ( { <partition_bound_expr> | MINVALUE | MAXVALUE } [, ...] )
  TO ( { <partition_bound_expr> | MINVALUE | MAXVALUE } [, ...] ) |
WITH ( MODULUS <numeric_literal>, REMAINDER <numeric_literal> )
```

Description

`CREATE FOREIGN TABLE` creates a new foreign table in the current database. The user who creates the foreign table becomes its owner.

If you schema-qualify the table name (for example, `CREATE FOREIGN TABLE myschema.mytable ...`), WarehousePG creates the table in the specified schema. Otherwise, the foreign table is created in the current schema. The name of the foreign table must be distinct from the name of any other foreign table, table, sequence, index, view, or materialized view in the same schema.

Because `CREATE FOREIGN TABLE` automatically creates a data type that represents the composite type corresponding to one row of the foreign table, foreign tables cannot have the same name as any existing data type in the same schema.

If the `PARTITION OF` clause is specified, then the table is created as a partition of parent_table with specified bounds.

To create a foreign table, you must have `USAGE` privilege on the foreign server, as well as `USAGE` privilege on all column types used in the table.

Parameters

IF NOT EXISTS Do not throw an error if a relation with the same name already exists. WarehousePG issues a notice in this case. Note that there is no guarantee that the existing relation is anything like the one that would have been created.

table_name The name (optionally schema-qualified) of the foreign table to create.

column_name The name of a column to create in the new foreign table.

data_type The data type of the column, including array specifiers.

COLLATE collation The `COLLATE` clause assigns a collation to the column (which must be of a collatable data type). If not specified, the column data type's default collation is used.

INHERITS (parent_table [, ...]) The optional `INHERITS` clause specifies a list of tables from which the new foreign table automatically inherits all columns. Parent tables can be plain tables or foreign tables. See the similar form of CREATE TABLE for more details.

PARTITION OF parent_table { FOR VALUES partition_bound_spec | DEFAULT } This form can be used to create the foreign table as partition of the given parent table with specified partition bound values. See the similar form of CREATE TABLE for more details. Note that it is currently not allowed to create the foreign table as a partition of the parent table if there are `UNIQUE` indexes on the parent table. (See also ALTER TABLE ATTACH PARTITION.)

CONSTRAINT constraint_name An optional name for a column or table constraint. If the constraint is violated, the constraint name is present in error messages, so constraint names like `col must be positive` can be used to communicate helpful constraint information to client applications. (Double-quotes are needed to specify constraint names that contain spaces.) If a constraint name is not specified, the system generates a name.

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NOT NULL The column is not allowed to contain null values.

NULL The column is allowed to contain null values. This is the default.

```
This clause is provided only for compatibility with non-standard SQL databases. Its use is discouraged in new applications.
```

CHECK (expression) [NO INHERIT] The `CHECK` clause specifies an expression producing a Boolean result which each row in the foreign table is expected to satisfy; that is, the expression should produce TRUE or UNKNOWN, never FALSE, for all rows in the foreign table. A check constraint specified as a column constraint should reference that column's value only, while an expression appearing in a table constraint can reference multiple columns. Currently, `CHECK` expressions cannot contain subqueries nor refer to variables other than columns of the current row. The system column `tableoid` may be referenced, but not any other system column. A constraint marked with `NO INHERIT` will not propagate to child tables.

DEFAULT default_expr The `DEFAULT` clause assigns a default value for the column whose definition it appears within. The value is any variable-free expression; WarehousePG does not allow subqueries and cross-references to other columns in the current table. The data type of the default expression must match the data type of the column. WarehousePG uses the default expression in any insert operation that does not specify a value for the column. If there is no default for a column, then the default is null.

GENERATED ALWAYS AS (generation_expr) STORED This clause creates the column as a generated column. The column cannot be written to, and when read the result of the specified expression will be returned. The keyword `STORED` is required to signify that the column will be computed on write. (The computed value will be presented to the foreign-data wrapper for storage and must be returned on reading.) The generation expression can refer to other columns in the table, but not other generated columns. Any functions and operators used must be immutable. References to other tables are not allowed.

server_name The name of an existing server to use for the foreign table. For details on defining a server, see CREATE SERVER.

OPTIONS (option 'value' [, ...]) The options for the new foreign table or one of its columns. While option names must be unique, a table option and a column option may have the same name. The option names and values are foreign-data wrapper-specific. WarehousePG validates the options and values using the foreign-data wrapper's validator_function.

mpp_execute { 'coordinator' | 'any' | 'all segments' } A WarehousePG-specific option that identifies the host from which the foreign-data wrapper reads or writes data:

```
-   `coordinator` \(the default\)—Read or write data from the coordinator host.
-   `any`—Read data from either the coordinator host or any one segment, depending on which path costs less.
-   `all segments`—Read or write data from all segments. To support this option value, the foreign-data wrapper must have a policy that matches the segments to
data.

> **Note** WarehousePG supports parallel writes to foreign tables only when you set `mpp_execute 'all segments'`.

Support for the foreign table `mpp_execute` option, and the specific modes, is foreign-data wrapper-specific.

The `mpp_execute` option can be specified in multiple commands: `CREATE FOREIGN TABLE`, `CREATE SERVER`, and `CREATE FOREIGN DATA WRAPPER`. The foreign table
setting takes precedence over the foreign server setting, followed by the foreign-data wrapper setting.
```

Notes

Constraints on foreign tables (such as `CHECK` or `NOT NULL` clauses) are not enforced by WarehousePG, and most foreign-data wrappers do not attempt to enforce them either; that is, the constraint is simply assumed to hold true. There would be little point in such enforcement since it would only apply to rows inserted or updated via the foreign table, and not to rows modified by other means, such as directly on the remote server. Instead, a constraint attached to a foreign table should represent a constraint that is being enforced by the remote server.

Some special-purpose foreign-data wrappers might be the only access mechanism for the data they access, and in that case it might be appropriate for the foreign-data wrapper itself to perform constraint enforcement. But you should not assume that a wrapper does that unless its documentation says so.

Although WarehousePG does not attempt to enforce constraints on foreign tables, it does assume that they are correct for purposes of query optimization. If there are rows visible in the foreign table that do not satisfy a declared constraint, queries on the table might produce errors or incorrect answers. It is the user's responsibility to ensure that the constraint definition matches reality.

> **Note:** When a foreign table is used as a partition of a partitioned table, there is an implicit constraint that its contents must satisfy the partitioning rule. Again, it is the user's responsibility to ensure that that is true, which is best done by installing a matching constraint on the remote server.

Within a partitioned table containing foreign-table partitions, an `UPDATE` that changes the partition key value can cause a row to be moved from a local partition to a foreign-table partition, provided the foreign-data wrapper supports tuple routing. However it is not currently possible to move a row from a foreign-table partition to another partition. An `UPDATE` that would require doing that will fail due to the partitioning constraint, assuming that that is properly enforced by the remote server.

Similar considerations apply to generated columns. Stored generated columns are computed on insert or update on the local WarehousePG server and handed to the foreign-data wrapper for writing out to the foreign data store, but it is not enforced that a query of the foreign table returns values for stored generated columns that are consistent with the generation expression. Again, this might result in incorrect query results.

Examples

Create a foreign table named `films` with the server named `film_server`:

```
CREATE FOREIGN TABLE films (
    code        char(5) NOT NULL,
    title       varchar(40) NOT NULL,
    did         integer NOT NULL,
    date_prod   date,
    kind        varchar(10),
    len         interval hour to minute
)
SERVER film_server;
```

Create foreign table `measurement_y2016m07`, which will be accessed through the server `server_07`, as a partition of the range partitioned table measurement:

```
CREATE FOREIGN TABLE measurement_y2016m07
    PARTITION OF measurement FOR VALUES FROM ('2016-07-01') TO ('2016-08-01')
    SERVER server_07;
```

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Compatibility

`CREATE FOREIGN TABLE` largely conforms to the SQL standard; however, much as with CREATE TABLE, WarehousePG permits `NULL` constraints and zero-column foreign tables. The ability to specify column default values is a WarehousePG extension, as is the `mpp_execute` option. Table inheritance, in the form defined by WarehousePG, is nonstandard.

See Also

ALTER FOREIGN TABLE, DROP FOREIGN TABLE, CREATE SERVER

Parent topic: SQL Commands

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7.1.61 CREATE FUNCTION

Defines a new function.

Synopsis

```
CREATE [OR REPLACE] FUNCTION <name>
    ( [ [<argmode>] [<argname>] <argtype> [ { DEFAULT | = } <default_expr> ] [, ...] ] )
      [ RETURNS <rettype>
        | RETURNS TABLE ( <column_name> <column_type> [, ...] ) ]
  { LANGUAGE <lang_name>
    | TRANSFORM { FOR TYPE <type_name> } [, ... ]
    | WINDOW
    | { IMMUTABLE | STABLE | VOLATILE }
    | [ NOT ] LEAKPROOF
    | { CALLED ON NULL INPUT | RETURNS NULL ON NULL INPUT | STRICT }
    | { [ EXTERNAL ] SECURITY INVOKER | [ EXTERNAL ] SECURITY DEFINER }
    | EXECUTE ON { ANY | COORDINATOR | ALL SEGMENTS | INITPLAN }
    | PARALLEL { UNSAFE | RESTRICTED | SAFE }
    | COST <execution_cost>
    | ROWS <result_rows>
    | SUPPORT <support_function>
    | SET <configuration_parameter> { TO <value> | = <value> | FROM CURRENT }
    | AS '<definition>'
    | AS '<obj_file>', '<link_symbol>'
    [ WITH ({ DESCRIBE = <describe_function> } [, ...] ) ]
  } ...
```

Description

`CREATE FUNCTION` defines a new function. `CREATE OR REPLACE FUNCTION` either creates a new function, or replaces an existing definition. To define a function, the user must have the `USAGE` privilege on the language.

If a schema name is included, then the function is created in the specified schema. Otherwise it is created in the current schema. The name of the new function must not match any existing function with the same input argument types in the same schema. However, functions of different argument types may share a name (overloading).

To update the current definition of an existing function, use `CREATE OR REPLACE FUNCTION`. It is not possible to change the name or argument types of a function this way (this would actually create a new, distinct function). Also, `CREATE OR REPLACE FUNCTION` will not let you change the return type of an existing function. To do that, you must drop and recreate the function. (When using `OUT` parameters, that means you cannot change the types of any `OUT` parameters except by dropping the function.)

When `CREATE OR REPLACE FUNCTION` is used to replace an existing function, the ownership and permissions of the function do not change. All other function properties are assigned the values specified or implied in the command. You must own the function to replace it (this includes being a member of the owning role).

If you drop and then recreate a function, the new function is not the same entity as the old; you will have to drop existing objects (rules, views, triggers, and so on) that refer to the old function. Use `CREATE OR REPLACE FUNCTION` to change a function definition without breaking objects that refer to the function. Also, ALTER FUNCTION can be used to change most of the auxiliary properties of an existing function.

The user that creates the function becomes the owner of the function.

To be able to create a function, you must have `USAGE` privilege on the argument types and the return type.

For more information about creating functions, refer to the User Defined Functions section of the PostgreSQL documentation.

Limited Use of VOLATILE and STABLE Functions

To prevent data from becoming out-of-sync across the segments in WarehousePG, any function classified as `STABLE` or `VOLATILE` cannot be run at the segment level if it contains SQL or modifies the database in any way. For example, functions such as `random()` or `timeofday()` are not allowed to run on distributed data in WarehousePG because they could potentially cause inconsistent data between the segment instances.

To ensure data consistency, `VOLATILE` and `STABLE` functions can safely be used in statements that are evaluated on and run from the coordinator. For example, the following statements are always run on the coordinator (statements without a `FROM` clause):

```
SELECT setval('myseq', 201);
SELECT foo();
```

In cases where a statement has a `FROM` clause containing a distributed table and the function used in the `FROM` clause simply returns a set of rows, execution may be allowed on the segments:

```
SELECT * FROM foo();
```

One exception to this rule are functions that return a table reference (`rangeFuncs`) or functions that use the `refCursor` data type. Note that you cannot return a `refcursor` from any kind of function in WarehousePG.

Function Volatility and EXECUTE ON Attributes

Volatility attributes (`IMMUTABLE`, `STABLE`, `VOLATILE`) and `EXECUTE ON` attributes specify two different aspects of function execution. In general, volatility indicates when the function is run, and `EXECUTE ON` indicates where it is run.

For example, a function defined with the `IMMUTABLE` attribute can be run at query planning time, while a function with the `VOLATILE` attribute must be run for every row in the query. A function with the `EXECUTE ON COORDINATOR` attribute is run only on the coordinator segment and a function with the `EXECUTE ON ALL SEGMENTS` attribute is run on all primary segment instances (not the coordinator).

See Using Functions and Operators in the *WarehousePG Administrator Guide*.

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Functions And Replicated Tables

A user-defined function that runs only `SELECT` commands on replicated tables can run on segments. Replicated tables, created with the `DISTRIBUTED REPLICATED` clause, store all of their rows on every segment. It is safe for a function to read them on the segments, but updates to replicated tables must run on the coordinator instance.

Parameters

name The name (optionally schema-qualified) of the function to create.

argmode The mode of an argument: either `IN`, `OUT`, `INOUT`, or `VARIADIC`. If omitted, the default is `IN`. Only `OUT` arguments can follow an argument declared as `VARIADIC`. Also, `OUT` and `INOUT` arguments cannot be used together with the `RETURNS TABLE` notation.

argname The name of an argument. Some languages (currently only SQL and PL/pgSQL) let you use the name in the function body. For other languages the name of an input argument is just extra documentation, so far as the function itself is concerned; but you can use input argument names when calling a function to improve readability. In any case, the name of an output argument is significant, since it defines the column name in the result row type. (If you omit the name for an output argument, the system will choose a default column name.)

argtype The data type(s) of the function's arguments (optionally schema-qualified), if any. The argument types may be base, composite, or domain types, or may reference the type of a table column.

Depending on the implementation language it may also be allowed to specify pseudotypes such as `cstring`. Pseudotypes indicate that the actual argument type is either incompletely specified, or outside the set of ordinary SQL data types.

The type of a column is referenced by writing `table_name.column_name%TYPE`. Using this feature can sometimes help make a function independent of changes to the definition of a table.

default_expr An expression to be used as the default value if the parameter is not specified. The expression must be coercible to the argument type of the parameter. Only input (including `INOUT`) parameters can have a default value. Each input parameter in the argument list that follows a parameter with a default value must have a default value as well.

rettype The return data type (optionally schema-qualified). The return type can be a base, composite, or domain type, or may reference the type of a table column. Depending on the implementation language it may also be allowed to specify pseudotypes such as `cstring`. If the function is not supposed to return a value, specify `void` as the return type.

When there are `OUT` or `INOUT` parameters, the `RETURNS` clause may be omitted. If present, it must agree with the result type implied by the output parameters `RECORD` if there are multiple output parameters, or the same type as the single output parameter.

The `SETOF` modifier indicates that the function will return a set of items, rather than a single item.

The type of a column is referenced by writing `table_name.column_name%TYPE`.

column_name The name of an output column in the `RETURNS TABLE` syntax. This is effectively another way of declaring a named `OUT` parameter, except that `RETURNS TABLE` also implies `RETURNS SETOF`.

column_type The data type of an output column in the `RETURNS TABLE` syntax.

lang_name The name of the language that the function is implemented in. May be `SQL`, `C`, `internal`, or the name of a user-defined procedural language, e.g. `plpgsql`. Enclosing the name in single quotes is deprecated and requires matching case.

TRANSFORM { FOR TYPE type_name } [, ...] } Lists which transforms a call to the function should apply. Transforms convert between SQL types and language-specific data types. Procedural language implementations usually have hardcoded knowledge of the built-in types, so those don't need to be listed here. If a procedural language implementation does not know how to handle a type and no transform is supplied, it will fall back to a default behavior for converting data types, but this depends on the implementation.

WINDOW `WINDOW` indicates that the function is a window function rather than a plain function. This is currently only useful for functions written in C. The `WINDOW` attribute cannot be changed when replacing an existing function definition.

IMMUTABLE STABLE VOLATILE These attributes inform the query optimizer about the behavior of the function. At most one choice may be specified. If none of these appear, `VOLATILE` is the default assumption. Since WarehousePG currently has limited use of `VOLATILE` functions, if a function is truly `IMMUTABLE`, you must declare it as so to be able to use it without restrictions.

`IMMUTABLE` indicates that the function cannot modify the database and always returns the same result when given the same argument values. It does not do database lookups or otherwise use information not directly present in its argument list. If this option is given, any call of the function with all-constant arguments can be immediately replaced with the function value.

`STABLE` indicates that the function cannot modify the database, and that within a single table scan it will consistently return the same result for the same argument values, but that its result could change across SQL statements. This is the appropriate selection for functions whose results depend on database lookups, parameter variables (such as the current time zone), and so on. Also note that the `current_timestamp()` family of functions qualify as stable, since their values do not change within a transaction.

`VOLATILE` indicates that the function value can change even within a single table scan, so no optimizations can be made. Relatively few database functions are volatile in this sense; some examples are `random()`, `timeofday()`. But note that any function that has side-effects must be classified volatile, even if its result is quite predictable, to prevent calls from being optimized away; an example is `setval()`.

LEAKPROOF `LEAKPROOF` indicates that the function has no side effects. It reveals no information about its arguments other than by its return value. For example, a function that throws an error message for some argument values but not others, or that includes the argument values in any error message, is not leakproof. This affects how the system executes queries against views created with the `security_barrier` option or tables with row level security enabled. The system will enforce conditions from security policies and security barrier views before any user-supplied conditions from the query itself that contain non-leakproof functions, in order to prevent the inadvertent exposure of data. Functions and operators marked as leakproof are assumed to be trustworthy, and may be executed before conditions from security policies and security barrier views. In addition, functions which do not take arguments or which are not passed any arguments from the security barrier view or table do not have to be marked as leakproof to be executed before security conditions. See CREATE VIEW. This option can only be set by the superuser.

CALLED ON NULL INPUT RETURNS NULL ON NULL INPUT STRICT `CALLED ON NULL INPUT` (the default) indicates that the function will be called normally when some of its arguments are null. It is then the function author's responsibility to check for null values if necessary and respond appropriately. `RETURNS NULL ON NULL INPUT` or `STRICT` indicates that the function always returns null whenever any of its arguments are null. If this parameter is specified, the function is not run when there are null arguments; instead a null result is assumed automatically.

[EXTERNAL] SECURITY INVOKER [EXTERNAL] SECURITY DEFINER `SECURITY INVOKER` (the default) indicates that the function is to be run with the privileges of the user that calls it. `SECURITY DEFINER` specifies that the function is to be run with the privileges of the user that created it. The key word `EXTERNAL` is allowed for SQL conformance, but it is optional since, unlike in SQL, this feature applies to all functions not just external ones.

EXECUTE ON ANY EXECUTE ON COORDINATOR EXECUTE ON ALL SEGMENTS EXECUTE ON INITPLAN The `EXECUTE ON` attributes specify where (coordinator or segment instance) a function runs when it is invoked during the query execution process.

`EXECUTE ON ANY` (the default) indicates that the function can be run on the coordinator, or any segment instance, and it returns the same result regardless of where it is run. WarehousePG determines where the function runs.

`EXECUTE ON COORDINATOR` indicates that the function must run only on the coordinator instance.

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`EXECUTE ON ALL SEGMENTS` indicates that the function must run on all primary segment instances, but not the coordinator, for each invocation. The overall result of the function is the `UNION ALL` of the results from all segment instances.

`EXECUTE ON INITPLAN` indicates that the function contains an SQL command that dispatches queries to the segment instances and requires special processing on the coordinator instance by WarehousePG when possible.

```
> **Note** `EXECUTE ON INITPLAN` is only supported in functions that are used in the `FROM` clause of a `CREATE TABLE AS` or `INSERT` command such as the
`get_data()` function in these commands.

```
CREATE TABLE t AS SELECT * FROM get_data();

INSERT INTO t1 SELECT * FROM get_data();
```

WarehousePG does not support the `EXECUTE ON INITPLAN` attribute in a function that is used in the `WITH` clause of a query, a CTE \(common table expression\).
For example, specifying `EXECUTE ON INITPLAN` in function `get_data()` in this CTE is not supported.

```
WITH tbl_a AS (SELECT * FROM get_data() )
   SELECT * from tbl_a
   UNION
   SELECT * FROM tbl_b;
```
```

For information about using `EXECUTE ON` attributes, see Notes.

PARALLEL `PARALLEL UNSAFE` indicates that the function can't be executed in parallel mode and the presence of such a function in an SQL statement forces a serial execution plan. This is the default. `PARALLEL RESTRICTED` indicates that the function can be executed in parallel mode, but the execution is restricted to parallel group leader. `PARALLEL SAFE` indicates that the function is safe to run in parallel mode without restriction. Functions should be labeled parallel unsafe if they modify any database state, or if they make changes to the transaction such as using sub-transactions, or if they access sequences or attempt to make persistent changes to settings (e.g., `setval()`). They should be labeled as parallel restricted if they access temporary tables, client connection state, cursors, prepared statements, or miscellaneous backend-local state which the system cannot synchronize in parallel mode (e.g., `setseed()` cannot be executed other than by the group leader because a change made by another process would not be reflected in the leader). In general, if a function is labeled as being safe when it is restricted or unsafe, or if it is labeled as being restricted when it is in fact unsafe, it may throw errors or produce wrong answers when used in a parallel query. C-language functions could in theory exhibit totally undefined behavior if mislabeled, since there is no way for the system to protect itself against arbitrary C code, but in most likely cases the result will be no worse than for any other function. If in doubt, functions should be labeled as `UNSAFE`, which is the default.

COST execution_cost A positive number identifying the estimated execution cost for the function, in units of cpu_operator_cost. If the function returns a set, execution_cost identifies the cost per returned row. If the cost is not specified, C-language and internal functions default to 1 unit, while functions in other languages default to 100 units. Larger values cause the planner to try to avoid evaluating the function more often than necessary.

ROWS result_rows A positive number giving the estimated number of rows that the planner should expect the function to return. This is only allowed when the function is declared to return a set. The default assumption is 1000 rows.

SUPPORT support_function The name (optionally schema-qualified) of a planner support function to use for this function. You must be superuser to use this option.

configuration_parameter value The `SET` clause applies a value to a session configuration parameter when the function is entered. The configuration parameter is restored to its prior value when the function exits. `SET FROM CURRENT` saves the value of the parameter that is current when `CREATE FUNCTION` is run as the value to be applied when the function is entered. If a `SET` clause is attached to a function, then the effects of a `SET LOCAL` command executed inside the function for the same variable are restricted to the function: the configuration parameter's prior value is still restored at function exit. However, an ordinary `SET` command (without `LOCAL`) overrides the `SET` clause, much as it would do for a previous `SET LOCAL` command: the effects of such a command will persist after function exit, unless the current transaction is rolled back. SeeSET for more information about allowed parameter names and values.

definition A string constant defining the function; the meaning depends on the language. It may be an internal function name, the path to an object file, an SQL command, or text in a procedural language.

It is often helpful to use dollar quoting (refer to Dollar-Quoted String Constants in the PostgreSQL documentation) to write the function definition string, rather than the normal single quote syntax. Without dollar quoting, any single quotes or backslashes in the function definition must be escaped by doubling them.

obj_file, link_symbol This form of the `AS` clause is used for dynamically loadable C language functions when the function name in the C language source code is not the same as the name of the SQL function. The string obj_file is the name of the file containing the dynamically loadable object, and is interpreted as for the LOAD command. The string link_symbol is the name of the function in the C language source code. If the link symbol is omitted, it is assumed to be the same as the name of the SQL function being defined. The C names of all functions must be different, so you must give overloaded SQL functions different C names (for example, use the argument types as part of the C names). When repeated `CREATE FUNCTION` calls refer to the same object file, the file is only loaded once per session. To unload and reload the file (perhaps during development), start a new session. Locating shared libraries either relative to `$libdir` (which is located at `$GPHOME/lib`) or through the dynamic library path (set by the `dynamic_library_path` server configuration parameter) will simplify version upgrades if the new installation is at a different location.

describe_function The name of a callback function to run when a query that calls this function is parsed. The callback function returns a tuple descriptor that indicates the result type.

Overloading

WarehousePG allows function overloading; that is, the same name can be used for several different functions so long as they have distinct input argument types. Whether or not you use it, this capability entails security precautions when calling functions in databases where some users mistrust other users; refer to Functions in the PostgreSQL documentation for more information.

Two functions are considered the same if they have the same names and input argument types, ignoring any `OUT` parameters. Thus for example these declarations conflict:

```
CREATE FUNCTION foo(int) ...
CREATE FUNCTION foo(int, out text) ...
```

Functions that have different argument type lists will not be considered to conflict at creation time, but if defaults are provided they might conflict in use. For example, consider:

```
CREATE FUNCTION foo(int) ...
CREATE FUNCTION foo(int, int default 42) ...
```

A call `foo(10)` will fail due to the ambiguity about which function should be called.

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Notes

Any compiled code (shared library files) for custom functions must be placed in the same location on every host in your WarehousePG cluster (coordinator and all segments). This location must also be in the `LD_LIBRARY_PATH` so that the server can locate the files. It is recommended that you locate shared libraries either relative to `$libdir` (which is located at `$GPHOME/lib`) or through the dynamic library path (set by the `dynamic_library_path` server configuration parameter) on all coordinator segment instances in the WarehousePG cluster.

The full SQL type syntax is allowed for input arguments and return value. However, parenthesized type modifiers (e.g., the precision field for type `numeric`) are discarded by `CREATE FUNCTION`. Thus for example `CREATE FUNCTION foo (varchar(10)) ...` is exactly the same as `CREATE FUNCTION foo (varchar) ...`.

When replacing an existing function with `CREATE OR REPLACE FUNCTION`, there are restrictions on changing parameter names. You cannot change the name already assigned to any input parameter (although you can add names to parameters that had none before). If there is more than one output parameter, you cannot change the names of the output parameters, because that would change the column names of the anonymous composite type that describes the function's result. These restrictions are made to ensure that existing calls of the function do not stop working when it is replaced.

If a function is declared `STRICT` with a `VARIADIC` argument, the strictness check tests that the variadic array as a whole is non-null. The function will still be called if the array has null elements.

Using Functions with Queries on Distributed Data

In some cases, WarehousePG does not support using functions in a query where the data in a table specified in the `FROM` clause is distributed over WarehousePG segments. As an example, this SQL query contains the function `func()`:

```
SELECT func(a) FROM table1;
```

The function is not supported for use in the query if all of the following conditions are met:

- The data of table `table1` is distributed over WarehousePG segments.
- The function `func()` reads or modifies data from distributed tables.
- The function `func()` returns more than one row or takes an argument (`a`) that comes from `table1`.

If any of the conditions are not met, the function is supported. Specifically, the function is supported if any of the following conditions apply:

- The function `func()` does not access data from distributed tables, or accesses data that is only on the WarehousePG coordinator.
- The table `table1` is a coordinator only table.
- The function `func()` returns only one row and only takes input arguments that are constant values. The function is supported if it can be changed to require no input arguments.

Using EXECUTE ON attributes

Most functions that run queries to access tables can only run on the coordinator. However, functions that run only `SELECT` queries on replicated tables can run on segments. If the function accesses a hash-distributed table or a randomly distributed table, the function should be defined with the `EXECUTE ON COORDINATOR` attribute. Otherwise, the function might return incorrect results when the function is used in a complicated query. Without the attribute, planner optimization might determine it would be beneficial to push the function invocation to segment instances.

These are limitations for functions defined with the `EXECUTE ON COORDINATOR` or `EXECUTE ON ALL SEGMENTS` attribute:

- The function must be a set-returning function.
- The function cannot be in the `FROM` clause of a query.
- The function cannot be in the `SELECT` list of a query with a `FROM` clause.
- A query that includes the function falls back from GPORCA to the Postgres-based planner.

The attribute `EXECUTE ON INITPLAN` indicates that the function contains an SQL command that dispatches queries to the segment instances and requires special processing on the coordinator instance by WarehousePG. When possible, WarehousePG handles the function on the coordinator instance in the following manner.

1. First, WarehousePG runs the function as part of an InitPlan node on the coordinator instance and holds the function output temporarily.
2. Then, in the MainPlan of the query plan, the function is called in an EntryDB (a special query executor (QE) that runs on the coordinator instance) and WarehousePG returns the data that was captured when the function was run as part of the InitPlan node. The function is not run in the MainPlan.

This simple example uses the function `get_data()` in a CTAS command to create a table using data from the table `country`. The function contains a `SELECT` command that retrieves data from the table `country` and uses the `EXECUTE ON INITPLAN` attribute.

```
CREATE TABLE country(
  c_id integer, c_name text, region int)
  DISTRIBUTED RANDOMLY;

INSERT INTO country VALUES (11,'INDIA', 1 ), (22,'CANADA', 2), (33,'USA', 3);

CREATE OR REPLACE FUNCTION get_data()
  RETURNS TABLE (
   c_id integer, c_name text
   )
AS $$
  SELECT
    c.c_id, c.c_name
  FROM
    country c;
$$
LANGUAGE SQL EXECUTE ON INITPLAN;

CREATE TABLE t AS SELECT * FROM get_data() DISTRIBUTED RANDOMLY;
```

If you view the query plan of the CTAS command with `EXPLAIN ANALYZE VERBOSE`, the plan shows that the function is run as part of an InitPlan node, and one of the listed slices is labeled as `entry db`. The query plan of a simple CTAS command without the function does not have an InitPlan node or an `entry db` slice.

If the function did not contain the `EXECUTE ON INITPLAN` attribute, the CTAS command returns the error `function cannot execute on a QE slice`.

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When a function uses the `EXECUTE ON INITPLAN` attribute, a command that uses the function such as `CREATE TABLE t AS SELECT * FROM get_data()` gathers the results of the function onto the coordinator segment and then redistributes the results to segment instances when inserting the data. If the function returns a large amount of data, the coordinator might become a bottleneck when gathering and redistributing data. Performance might improve if you rewrite the function to run the CTAS command in the user defined function and use the table name as an input parameter. In this example, the function runs a CTAS command and does not require the `EXECUTE ON INITPLAN` attribute. Running the `SELECT` command creates the table `t1` using the function that runs the CTAS command.

```
CREATE OR REPLACE FUNCTION my_ctas(_tbl text) RETURNS VOID AS
$$
BEGIN
  EXECUTE format('CREATE TABLE %s AS SELECT c.c_id, c.c_name FROM country c DISTRIBUTED RANDOMLY', _tbl);
END
$$
LANGUAGE plpgsql;

SELECT my_ctas('t1');
```

Examples

Add two integers using a SQL function:

```
CREATE FUNCTION add(integer, integer) RETURNS integer
    AS 'select $1 + $2;'
    LANGUAGE SQL
    IMMUTABLE
    RETURNS NULL ON NULL INPUT;
```

Increment an integer, making use of an argument name, in PL/pgSQL:

```
CREATE OR REPLACE FUNCTION increment(i integer) RETURNS
integer AS $$
        BEGIN
                RETURN i + 1;
        END;
$$ LANGUAGE plpgsql;
```

Return a record containing multiple output parameters:

```
CREATE FUNCTION dup(in int, out f1 int, out f2 text)
    AS $$ SELECT $1, CAST($1 AS text) || ' is text' $$
    LANGUAGE SQL;

SELECT * FROM dup(42);
```

You can do the same thing more verbosely with an explicitly named composite type:

```
CREATE TYPE dup_result AS (f1 int, f2 text);

CREATE FUNCTION dup(int) RETURNS dup_result
    AS $$ SELECT $1, CAST($1 AS text) || ' is text' $$
    LANGUAGE SQL;

SELECT * FROM dup(42);
```

Another way to return multiple columns is to use a `TABLE` function:

```
CREATE FUNCTION dup(int) RETURNS TABLE(f1 int, f2 text)
    AS $$ SELECT $1, CAST($1 AS text) || ' is text' $$
    LANGUAGE SQL;

SELECT * FROM dup(42);
```

However, a `TABLE` function is different from the preceding examples, because it actually returns a set of records, not just one record.

Increase the default segment host memory per query for a PL/pgSQL function:

```
CREATE OR REPLACE FUNCTION function_with_query() RETURNS
SETOF text AS $$
        BEGIN
                RETURN QUERY
                EXPLAIN ANALYZE SELECT * FROM large_table;
        END;
$$ LANGUAGE plpgsql
SET statement_mem='256MB';
```

Use polymorphic types to return an `ENUM` array:

```
CREATE TYPE rainbow AS ENUM('red','orange','yellow','green','blue','indigo','violet');
CREATE FUNCTION return_enum_as_array( anyenum, anyelement, anyelement )
    RETURNS TABLE (ae anyenum, aa anyarray) AS $$
    SELECT $1, array[$2, $3]
$$ LANGUAGE SQL STABLE;

SELECT * FROM return_enum_as_array('red'::rainbow, 'green'::rainbow, 'blue'::rainbow);
```

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This function is defined with the `EXECUTE ON ALL SEGMENTS` to run on all primary segment instances. The `SELECT` command runs the function that returns the time it was run on each segment instance.

```
CREATE FUNCTION run_on_segs (text) returns setof text as $$
  begin
    return next ($1 || ' - ' || now()::text );
  end;
 $$ language plpgsql VOLATILE EXECUTE ON ALL SEGMENTS;

SELECT run_on_segs('my test');
```

This function looks up a part name in the parts table. The parts table is replicated, so the function can run on the coordinator or on the primary segments.

```
CREATE OR REPLACE FUNCTION get_part_name(partno int) RETURNS text AS
$$
DECLARE
   result text := ' ';
BEGIN
    SELECT part_name INTO result FROM parts WHERE part_id = partno;
    RETURN result;
END;
$$ LANGUAGE plpgsql;
```

If you run `SELECT get_part_name(100);` at the coordinator the function runs on the coordinator. (The coordinator instance directs the query to a single primary segment.) If orders is a distributed table and you run the following query, the `get_part_name()` function runs on the primary segments.

```
`SELECT order_id, get_part_name(orders.part_no) FROM orders;`
```

Writing SECURITY DEFINER Functions Safely

Because a `SECURITY DEFINER` function is executed with the privileges of the user that created it, care is needed to ensure that the function cannot be misused. For security, `search_path` should be set to exclude any schemas writable by untrusted users. This prevents malicious users from creating objects that mask objects used by the function. Particularly important in this regard is the temporary-table schema, which is searched first by default, and is normally writable by anyone. A secure arrangement can be had by forcing the temporary schema to be searched last. To do this, write `pg_temp` as the last entry in `search_path`. This function illustrates safe usage:

```
CREATE FUNCTION check_password(uname TEXT, pass TEXT)
RETURNS BOOLEAN AS $$
DECLARE passed BOOLEAN;
BEGIN
        SELECT  (pwd = $2) INTO passed
        FROM    pwds
        WHERE   username = $1;

        RETURN passed;
END;
$$  LANGUAGE plpgsql
    SECURITY DEFINER
    -- Set a secure search_path: trusted schema(s), then 'pg_temp'.
    SET search_path = admin, pg_temp;
```

The `SET` option was not available in earlier versions of WarehousePG, and so older functions may contain rather complicated logic to save, set, and restore `search_path`. The `SET` option is far easier to use for this purpose.

Another point to keep in mind is that by default, execute privilege is granted to `PUBLIC` for newly created functions (see GRANT for more information). Frequently you will wish to restrict use of a security definer function to only some users. To do that, you must revoke the default `PUBLIC` privileges and then grant `EXECUTE` privilege selectively. To avoid having a window where the new function is accessible to all, create it and set the privileges within a single transaction. For example:

```
BEGIN;
CREATE FUNCTION check_password(uname TEXT, pass TEXT) ... SECURITY DEFINER;
REVOKE ALL ON FUNCTION check_password(uname TEXT, pass TEXT) FROM PUBLIC;
GRANT EXECUTE ON FUNCTION check_password(uname TEXT, pass TEXT) TO admins;
COMMIT;
```

Compatibility

`CREATE FUNCTION` is defined in SQL:1999 and later. The WarehousePG version is similar but not fully compatible. The attributes are not portable, neither are the different available languages.

For compatibility with some other database systems, argmode can be written either before or after argname. But only the first way is standard-compliant.

For parameter defaults, the SQL standard specifies only the syntax with the `DEFAULT` key word. The syntax with `=` is used in T-SQL and Firebird.

See Also

ALTER FUNCTION, DROP FUNCTION, GRANT, LOAD, REVOKE, createlang

Parent topic: SQL Commands

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7.1.62 CREATE GROUP

Defines a new database role.

Synopsis

```
CREATE GROUP <name> [[WITH] <option> [ ... ]]
```

where option can be:

```
      SUPERUSER | NOSUPERUSER
    | CREATEDB | NOCREATEDB
    | CREATEROLE | NOCREATEROLE
    | CREATEEXTTABLE | NOCREATEEXTTABLE
      [ ( <attribute>='<value>'[, ...] ) ]
           where <attributes> and <value> are:
           type='readable'|'writable'
           protocol='gpfdist'|'http'
    | INHERIT | NOINHERIT
    | LOGIN | NOLOGIN
    | REPLICATION | NOREPLICATION
    | BYPASSRLS | NOBYPASSRLS
    | CONNECTION LIMIT <connlimit>
    | [ ENCRYPTED | UNENCRYPTED ] PASSWORD '<password>' | PASSWORD NULL
    | VALID UNTIL '<timestamp>'
    | IN ROLE <role_name> [, ...]
    | IN GROUP <role_name> [, ...]
    | ROLE <role_name> [, ...]
    | ADMIN <role_name> [, ...]
    | USER <role_name> [, ...]
    | SYSID <uid> [, ...]
    | RESOURCE QUEUE <queue_name>
    | RESOURCE GROUP <group_name>
    | [ DENY <deny_point> ]
    | [ DENY BETWEEN <deny_point> AND <deny_point>]
```

Description

`CREATE GROUP` is an alias for CREATE ROLE.

Compatibility

There is no `CREATE GROUP` statement in the SQL standard.

See Also

CREATE ROLE

Parent topic: SQL Commands

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7.1.63 CREATE INDEX

Defines a new index.

Synopsis

```
CREATE [UNIQUE] INDEX [[IF NOT EXISTS] <name>] ON [ONLY] <table_name> [USING <method>]
       ( {<column_name> | (<expression>)} [COLLATE <collation>] [<opclass>] [ ASC | DESC ] [ NULLS { FIRST | LAST } ] [, ...] )
       [ INCLUDE ( column_name [, ...] ) ]
       [ WITH ( <storage_parameter> [= <value>] [, ... ] ) ]
       [ TABLESPACE <tablespace_name> ]
       [ WHERE <predicate> ]
```

Description

`CREATE INDEX` constructs an index on the specified column(s) of the specified table or materialized view. Indexes are primarily used to enhance database performance (though inappropriate use can result in slower performance).

The key field(s) for the index are specified as column names, or alternatively as expressions written in parentheses. Multiple fields can be specified if the index method supports multicolumn indexes.

An index field can be an expression computed from the values of one or more columns of the table row. This feature can be used to obtain fast access to data based on some transformation of the basic data. For example, an index computed on `upper(col)` would allow the clause `WHERE upper(col) = 'JIM'` to use an index.

WarehousePG provides the index methods B-tree, hash, bitmap, GiST, SP-GiST, GIN, and BRIN. Users can also define their own index methods, but that is fairly complicated.

When the `WHERE` clause is present, a partial index is created. A partial index is an index that contains entries for only a portion of a table, usually a portion that is more useful for indexing than the rest of the table. For example, if you have a table that contains both billed and unbilled orders where the unbilled orders take up a small fraction of the total table and yet is most often selected, you can improve performance by creating an index on just that portion. Another possible application is to use `WHERE` with `UNIQUE` to enforce uniqueness over a subset of a table. See Partial Indexes in the PostgreSQL documentation for more information.

The expression used in the `WHERE` clause may refer only to columns of the underlying table, but it can use all columns, not just the ones being indexed. Subqueries and aggregate expressions are also forbidden in `WHERE`. The same restrictions apply to index fields that are expressions.

All functions and operators used in an index definition must be immutable. Their results must depend only on their arguments and never on any outside influence (such as the contents of another table or the current time). This restriction ensures that the behavior of the index is well-defined. To use a user-defined function in an index expression or `WHERE` clause, remember to mark the function `IMMUTABLE` when you create it.

Parameters

UNIQUE Checks for duplicate values in the table when the index is created (if data already exist) and each time data is added. Duplicate entries will generate an error. Unique indexes only apply to B-tree indexes. Additional restrictions apply when unique indexes are applied to partitioned tables; see CREATE TABLE.

IF NOT EXISTS Do not throw an error if a relation with the same name already exists. A notice is issued in this case. Note that there is no guarantee that the existing index is anything like the one that would have been created. Index name is required when `IF NOT EXISTS` is specified.

INCLUDE The optional `INCLUDE` clause specifies a list of columns which will be included in the index as non-key columns. A non-key column cannot be used in an index scan search qualification, and it is disregarded for purposes of any uniqueness or exclusion constraint enforced by the index. However, an index-only scan can return the contents of non-key columns without having to visit the index's table, since they are available directly from the index entry. Thus, addition of non-key columns allows index-only scans to be used for queries that otherwise could not use them.

Be conservative about adding non-key columns to an index, especially wide columns. If an index tuple exceeds the maximum size allowed for the index type, data insertion fails. In any case, non-key columns duplicate data from the index's table and bloat the size of the index, thus potentially slowing searches.

Columns listed in the `INCLUDE` clause don't need appropriate operator classes; the clause can include columns whose data types don't have operator classes defined for a given access method.

Expressions are not supported as included columns since they cannot be used in index-only scans.

Currently, the B-tree and the GiST index access methods support `INCLUDE`. In B-tree and the GiST indexes, the values of columns listed in the `INCLUDE` clause are included in leaf tuples which correspond to heap tuples, but are not included in upper-level index entries used for tree navigation.

name The name of the index to be created. The index is always created in the same schema as its parent table. If the name is omitted, WarehousePG chooses a suitable name based on the parent table's name and the indexed column name(s).

ONLY Indicates not to recurse creating indexes on partitions, if the table is partitioned. The default is to recurse.

table_name The name (optionally schema-qualified) of the table to be indexed.

method The name of the index method to be used. Choices are `btree`, `bitmap`, `hash`, `gist`, `spgist`, `gin`, and `brin`. The default method is `btree`.

GPORCA supports only B-tree, bitmap, GiST, GIN, and BRIN indexes. GPORCA ignores indexes created with unsupported indexing methods.

column_name The name of a column of the table on which to create the index.

expression An expression based on one or more columns of the table. The expression usually must be written with surrounding parentheses, as shown in the syntax. However, the parentheses may be omitted if the expression has the form of a function call.

collation The name of the collation to use for the index. By default, the index uses the collation declared for the column to be indexed or the result collation of the expression to be indexed. Indexes with non-default collations can be useful for queries that involve expressions using non-default collations.

opclass The name of an operator class.

ASC Specifies ascending sort order (which is the default).

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DESC Specifies descending sort order.

NULLS FIRST Specifies that nulls sort before non-nulls. This is the default when `DESC` is specified.

NULLS LAST Specifies that nulls sort after non-nulls. This is the default when `DESC` is not specified.

storage_parameter The name of an index-method-specific storage parameter. Each index method has its own set of allowed storage parameters. See Index Storage Parameters for details.

tablespace_name The tablespace in which to create the index. If not specified,default_tablespace is consulted, or temp_tablespaces for indexes on temporary tables.

predicate The constraint expression for a partial index.

Index Storage Parameters

The optional `WITH` clause specifies *storage parameters* for the index. Each index method has its own set of allowed storage parameters. The B-tree, bitmap, hash, GiST, and SP-GiST index methods all accept this parameter:

`fillfactor` The `fillfactor` for an index is a percentage that determines how full the index method will try to pack index pages. For B-trees, leaf pages are filled to this percentage during initial index build, and also when extending the index at the right (adding new largest key values). If pages subsequently become completely full, they will be split, leading to gradual degradation in the index's efficiency. B-trees use a default fillfactor of 90, but any integer value from 10 to 100 can be selected. If the table is static then fillfactor 100 is best to minimize the index's physical size, but for heavily updated tables a smaller fillfactor is better to minimize the need for page splits. The other index methods use fillfactor in different but roughly analogous ways; the default fillfactor varies between methods.

B-tree indexes additionally accept this parameter:

vacuum_cleanup_index_scale_factor Per-index value for `vacuum_cleanup_index_scale_factor`.

GiST indexes additionally accept this parameter:

`buffering` Determines whether WarehousePG builds the index using the buffering build technique described in GiST buffering build in the PostgreSQL documentation. With `OFF` it is deactivated, with `ON` it is activated, and with `AUTO` it is initially deactivated, but turned on on-the-fly once the index size reaches effective_cache_size. The default is `AUTO`.

GIN indexes accept different parameters:

`fastupdate` This setting controls usage of the fast update technique described in GIN Fast Update Technique in the PostgreSQL documentation. It is a Boolean parameter that deactivates or activates the GIN index fast update technique. A value of `ON` activates fast update (the default), and `OFF` deactivates it.

Note: Turning `fastupdate` off via `ALTER INDEX` prevents future insertions from going into the list of pending index entries, but does not in itself flush previous entries. You might want to `VACUUM` the table or call `gin_clean_pending_list()` function afterward to ensure the pending list is emptied.

gin_pending_list_limit Custom `gin_pending_list_limit` parameter. This value is specified in kilobytes.

BRIN indexes accept different parameters:

pages_per_range Defines the number of table blocks that make up one block range for each entry of a BRIN index (see the BRIN Index Introduction in the PostgreSQL documentation for details). The default is 128.

autosummarize Defines whether a summarization run is queued for the previous page range whenever an insertion is detected on the next one. See [BRIN Index Maintenance] (https://www.postgresql.org/docs/12/brin-intro.html#BRIN-OPERATION) in the PostgreSQL documentation for more information. The default is `off`.

Notes

Refer to the Indexes topics in the PostgreSQL documentation for information about when indexes can be used, when they are not used, and in which particular situations they can be useful.

Currently, only the B-tree, bitmap, GiST, GIN, and BRIN index methods support multicolumn indexes. You can specify up to 32 fields by default. Only B-tree currently supports unique indexes.

An operator class can be specified for each column of an index. The operator class identifies the operators to be used by the index for that column. For example, a B-tree index on four-byte integers would use the `int4_ops` class; this operator class includes comparison functions for four-byte integers. In practice the default operator class for the column's data type is usually sufficient. The main point of having operator classes is that for some data types, there could be more than one meaningful ordering. For example, we might want to sort a complex-number data type either by absolute value or by real part. We could do this by defining two operator classes for the data type and then selecting the proper class when creating an index. Refer to Operator Classes and Operator Families and Interfacing Extensions to Indexes in the PostgreSQL documentation for more information about operator classes.

When `CREATE INDEX` is invoked on a partitioned table, the default behavior is to recurse to all partitions to ensure they all have matching indexes. Each partition is first checked to determine whether an equivalent index already exists, and if so, that index will become attached as a partition index to the index being created, which will become its parent index. If no matching index exists, a new index will be created and automatically attached; the name of the new index in each partition will be determined as if no index name had been specified in the command. If the `ONLY` option is specified, no recursion is done, and the index is marked invalid. (`ALTER INDEX ... ATTACH PARTITION` marks the index valid, once all partitions acquire matching indexes.) Note, however, that any partition that is created in the future using `CREATE TABLE ... PARTITION OF` or `ALTER TABLE ... ADD PARTITION` will automatically have a matching index, regardless of whether `ONLY` is specified

For index methods that support ordered scans (currently, only B-tree), you can specify the optional clauses `ASC`, `DESC`, `NULLS FIRST`, and/or `NULLS LAST` to modify the sort ordering of the index. Since an ordered index can be scanned either forward or backward, it is not normally useful to create a single-column `DESC` index — that sort ordering is already available with a regular index. The value of these options is that multicolumn indexes can be created that match the sort ordering requested by a mixed-ordering query, such as `SELECT ... ORDER BY x ASC, y DESC`. The `NULLS` options are useful if you need to support "nulls sort low" behavior, rather than the default "nulls sort high", in queries that depend on indexes to avoid sorting steps.

The system regularly collects statistics on all of a table's columns. Newly-created non-expression indexes can immediately use these statistics to determine an index's usefulness. For new expression indexes, you must run ANALYZE to generate statistics for these indexes.

For most index methods, the speed of creating an index is dependent on the setting of maintenance_work_mem. Larger values will reduce the time needed for index creation, so long as you don't make it larger than the amount of memory really available, which would drive the machine into swapping.

`bitmap` indexes perform best for columns that have between 100 and 100,000 distinct values. For a column with more than 100,000 distinct values, the performance and space efficiency of a bitmap index decline. The size of a bitmap index is proportional to the number of rows in the table times the number of distinct values in the indexed column.

Use DROP INDEX to remove an index.

Like any long-running transaction, `CREATE INDEX` on a table can affect which tuples can be removed by concurrent `VACUUM` on any other table.

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Prior releases of WarehousePG also had an R-tree index method. This method has been removed because it had no significant advantages over the GiST method. If `USING rtree` is specified, `CREATE INDEX` will interpret it as `USING gist`, to simplify conversion of old databases to GiST.

Examples

To create a unique B-tree index on the column `title` in the table `films`:

```
CREATE UNIQUE INDEX title_idx ON films (title);
```

To create a B-tree index on the column `title` with included columns `director` and `rating` in the table `films`:

```
CREATE INDEX title_idx ON films (title) INCLUDE (director, rating);
```

To create an index on the expression `lower(title)`, allowing efficient case-insensitive searches:

```
CREATE INDEX ON films ((lower(title)));
```

(In this example we have chosen to omit the index name, so the system will choose a name, typically `films_lower_idx`.)

To create an index with non-default collation:

```
CREATE INDEX title_idx_german ON films (title COLLATE "de_DE");
```

To create an index with non-default sort ordering of nulls:

```
CREATE INDEX title_idx_nulls_low ON films (title NULLS FIRST);
```

To create an index with non-default fill factor:

```
CREATE UNIQUE INDEX title_idx ON films (title) WITH
(fillfactor = 70);
```

To create a GIN index with fast updates deactivated:

```
CREATE INDEX gin_idx ON documents_table USING gin (locations) WITH (fastupdate = off);
```

To create an index on the column `code` in the table `films` and have the index reside in the tablespace `indexspace`:

```
CREATE INDEX code_idx ON films (code) TABLESPACE indexspace;
```

To create a GiST index on a point attribute so that we can efficiently use box operators on the result of the conversion function:

```
CREATE INDEX pointloc ON points USING gist (box(location,location));
SELECT * FROM points WHERE box(location,location) && '(0,0),(1,1)'::box;
```

Compatibility

`CREATE INDEX` is a WarehousePG extension to the SQL standard. There are no provisions for indexes in the SQL standard.

WarehousePG does not support the concurrent creation of indexes (`CONCURRENTLY` keyword is not supported).

See Also

ALTER INDEX, DROP INDEX

Parent topic: SQL Commands

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7.1.64 CREATE LANGUAGE

Defines a new procedural language.

Synopsis

```
CREATE [ OR REPLACE ] [ PROCEDURAL ] LANGUAGE <name>

CREATE [ OR REPLACE ] [ TRUSTED ] [ PROCEDURAL ] LANGUAGE <name>
    HANDLER <call_handler>
   [ INLINE <inline_handler> ]
   [ VALIDATOR <valfunction> ]
```

Description

`CREATE LANGUAGE` registers a new procedural language with a WarehousePG. Subsequently, functions and procedures can be defined in this new language.

> **Note** Procedural languages for WarehousePG have been made into "extensions," and should therefore be installed with CREATE EXTENSION, not `CREATE LANGUAGE`. Using `CREATE LANGUAGE` directly should be restricted to extension installation scripts. If you have a "bare" language in your database, perhaps as a result of an upgrade, you can convert it to an extension using `CREATE EXTENSION <langname> FROM unpackaged`.

`CREATE LANGUAGE` effectively associates the language name with handler function(s) that are responsible for executing functions written in the language.

There are two forms of the `CREATE LANGUAGE` command. In the first form, the user supplies just the name of the desired language, and the WarehousePG server consults the `pg_pltemplate` system catalog to determine the correct parameters. In the second form, the user supplies the language parameters along with the language name. The second form can be used to create a language that is not defined in `pg_pltemplate`, but this approach is considered obsolete.

When the server finds an entry in the `pg_pltemplate` catalog for the given language name, it will use the catalog data even if the command includes language parameters. This behavior simplifies loading of old dump files, which are likely to contain out-of-date information about language support functions.

Ordinarily, the user must have the WarehousePG superuser privilege to register a new language. However, the owner of a database can register a new language within that database if the language is listed in the `pg_pltemplate` catalog and is marked as allowed to be created by database owners (`tmpldbacreate` is `true`). The default is that trusted languages can be created by database owners, but this can be adjusted by superusers by modifying the contents of `pg_pltemplate`. The creator of a language becomes its owner and can later drop it, rename it, or assign it to a new owner.

`CREATE OR REPLACE LANGUAGE` will either create a new language, or replace an existing definition. If the language already exists, its parameters are updated according to the values specified or taken from `pg_pltemplate`, but the language's ownership and permissions settings do not change, and any existing functions written in the language are assumed to still be valid. In addition to the normal privilege requirements for creating a language, the user must be superuser or owner of the existing language. The `REPLACE` case is mainly meant to be used to ensure that the language exists. If the language has a `pg_pltemplate` entry then `REPLACE` will not actually change anything about an existing definition, except in the unusual case where the `pg_pltemplate` entry has been modified since the language was created.

Parameters

TRUSTED `TRUSTED` specifies that the language does not grant access to data that the user would not otherwise have. If this key word is omitted when registering the language, only users with the WarehousePG superuser privilege can use this language to create new functions.

PROCEDURAL This is a noise word.

name The name of the new procedural language. The name must be unique among the languages in the database. For backward compatibility, the name can be enclosed by single quotes.

HANDLER call_handler The name of a previously registered function that will be called to run the procedural language's functions. The call handler for a procedural language must be written in a compiled language such as C with version 1 call convention and registered with WarehousePG as a function taking no arguments and returning the `language_handler` type, a placeholder type that is simply used to identify the function as a call handler.

INLINE inline_handler The name of a previously registered function that is called to run an anonymous code block in this language that is created with the DO command. If no inline_handler function is specified, the language does not support anonymous code blocks. The handler function must take one argument of type `internal`, which is the DO command internal representation. The function typically returns `void`. The return value of the handler is ignored.

VALIDATOR valfunction The name of a previously registered function that will be called when a new function in the language is created, to validate the new function. If no validator function is specified, then WarehousePG will not check a new function when it is created. The validator function must take one argument of type `oid`, which will be the OID of the to-be-created function, and will typically return `void`. A validator function would typically inspect the function body for syntactical correctness, but it can also look at other properties of the function, for example if the language cannot handle certain argument types. To signal an error, the validator function should use the `ereport()` function. The return value of the function is ignored.

> **Note** The `TRUSTED` option and the support function name(s) are ignored if the server has an entry for the specified language name in `pg_pltemplate`.

Notes

Use DROP LANGUAGE to drop procedural languages.

The system catalog pg_language records information about the currently installed languages. Also, the psql command `\dL` lists the installed languages.

To create functions in a procedural language, a user must have the `USAGE` privilege for the language. By default, `USAGE` is granted to `PUBLIC` (everyone) for trusted languages. This may be revoked if desired.

Procedural languages are local to individual databases. However, a language can be installed into the `template1` database, which will cause it to be available automatically in all subsequently-created databases.

The call handler function, the inline handler function (if any), and the validator function (if any) must already exist if the server does not have an entry for the language in `pg_pltemplate`. But when there is an entry, the functions need not already exist; they will be automatically defined if not present in the database. (This might result in `CREATE LANGUAGE` failing, if the shared library that implements the language is not available in the installation.)

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Examples

The preferred way of creating any of the standard procedural languages is to use `CREATE EXTENSION` instead of `CREATE LANGUAGE`. For example:

```
CREATE EXTENSION plperl;
```

For a language not known in the `pg_pltemplate` catalog, a sequence such as this is needed:

```
CREATE FUNCTION plsample_call_handler() RETURNS
language_handler
    AS '$libdir/plsample'
    LANGUAGE C;
CREATE LANGUAGE plsample
    HANDLER plsample_call_handler;
```

Compatibility

`CREATE LANGUAGE` is a WarehousePG extension.

See Also

ALTER LANGUAGE, CREATE EXTENSION, CREATE FUNCTION, DROP LANGUAGE, GRANT, DO

Parent topic: SQL Commands

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7.1.65 CREATE MATERIALIZED VIEW

Defines a new materialized view.

Synopsis

```
CREATE MATERIALIZED VIEW [ IF  NOT EXISTS ] <table_name>
    [ (<column_name> [, ...] ) ]
    [ USING <method> ]
    [ WITH ( <storage_parameter> [= <value>] [, ... ] ) ]
    [ TABLESPACE <tablespace_name> ]
    AS <query>
    [ WITH [ NO ] DATA ]
    [DISTRIBUTED {| BY <column> [<opclass>], [ ... ] | RANDOMLY | REPLICATED }]
```

Description

`CREATE MATERIALIZED VIEW` defines a materialized view of a query. The query is run and used to populate the view at the time the command is issued (unless `WITH NO DATA` is used) and can be refreshed later using REFRESH MATERIALIZED VIEW.

`CREATE MATERIALIZED VIEW` is similar to `CREATE TABLE AS`, except that it also remembers the query used to initialize the view, so that it can be refreshed later upon demand. To refresh materialized view data, use the `REFRESH MATERIALIZED VIEW` command. A materialized view has many of the same properties as a table, but there is no support for temporary materialized views.

Parameters

IF NOT EXISTS Do not throw an error if a materialized view with the same name already exists. A notice is issued in this case. Note that there is no guarantee that the existing materialized view is anything like the one that would have been created.

table_name The name (optionally schema-qualified) of the materialized view to be created.

column_name The name of a column in the new materialized view. The column names are assigned based on position. The first column name is assigned to the first column of the query result, and so on. If a column name is not provided, it is taken from the output column names of the query.

USING method This optional clause specifies the table access method to use to store the contents for the new materialized view; the method needs be an access method of type `TABLE`. If this option is not specified, the default table access method is chosen for the new materialized view. See default_table_access_method for more information.

WITH (storage_parameter [= value] [, ...]) This clause specifies optional storage parameters for the materialized view. All parameters supported for `CREATE TABLE` are also supported for `CREATE MATERIALIZED VIEW`. See CREATE TABLE for more information.

TABLESPACE tablespace_name The tablespace_name is the name of the tablespace in which the new materialized view is to be created. If not specified, server configuration parameter default_tablespace is consulted.

query A SELECT, TABLE, or VALUES command. This query will run within a security-restricted operation; in particular, calls to functions that themselves create temporary tables will fail.

WITH [NO] DATA This clause specifies whether or not the materialized view should be populated with data at creation time. `WITH DATA` is the default, populate the materialized view. For `WITH NO DATA`, the materialized view is not populated with data, is flagged as unscannable, and cannot be queried until `REFRESH MATERIALIZED VIEW` is used to populate the materialized view.

DISTRIBUTED BY (column [opclass], [...]) DISTRIBUTED RANDOMLY DISTRIBUTED REPLICATED Used to declare the WarehousePG distribution policy for the materialized view data. For information about a table distribution policy, see CREATE TABLE.

Notes

Materialized views are read only. The system will not allow an `INSERT`, `UPDATE`, or `DELETE` on a materialized view. Use `REFRESH MATERIALIZED VIEW` to update the materialized view data.

If you want the data to be ordered upon generation, you must use an `ORDER BY` clause in the materialized view query. However, if a materialized view query contains an `ORDER BY` or `SORT` clause, the data is not guaranteed to be ordered or sorted if `SELECT` is performed on the materialized view.

Examples

Create a view consisting of all comedy films:

```
CREATE MATERIALIZED VIEW comedies AS SELECT * FROM films
WHERE kind = 'comedy';
```

This will create a view containing the columns that are in the `film` table at the time of view creation. Though `*` was used to create the materialized view, columns added later to the table will not be part of the view.

Create a view that gets the top ten ranked baby names:

```
CREATE MATERIALIZED VIEW topten AS SELECT name, rank, gender, year FROM
names, rank WHERE rank < '11' AND names.id=rank.id;
```

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Compatibility

`CREATE MATERIALIZED VIEW` is a WarehousePG extension of the SQL standard.

See Also

SELECT, VALUES, CREATE VIEW, ALTER MATERIALIZED VIEW, DROP MATERIALIZED VIEW, REFRESH MATERIALIZED VIEW

Parent topic: SQL Commands

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7.1.66 CREATE OPERATOR

Defines a new operator.

Synopsis

```
CREATE OPERATOR <name> (
       { FUNCTION | PROCEDURE } = <function\_name>
       [, LEFTARG = <left_type>] [, RIGHTARG = <right_type>]
       [, COMMUTATOR = <com_op>] [, NEGATOR = <neg_op>]
       [, RESTRICT = <res_proc>] [, JOIN = <join_proc>]
       [, HASHES] [, MERGES] )
```

Description

`CREATE OPERATOR` defines a new operator. The user who defines an operator becomes its owner. If a schema name is given, then the operator is created in the specified schema. Otherwise, it is created in the current schema.

The operator name is a sequence of up to `NAMEDATALEN`-1 (63 by default) characters from the following list: `+ - * / < > = ~ ! @ # % ^ & | ` ?` .

There are a few restrictions on your choice of name:

- `--` and `/*` cannot appear anywhere in an operator name, since they will be taken as the start of a comment.
- A multicharacter operator name cannot end in `+` or `-`, unless the name also contains at least one of these characters: `~ ! @ # % ^ & | ` ?`

  For example, `@-` is an allowed operator name, but `*-` is not. This restriction allows WarehousePG to parse SQL-compliant commands without requiring spaces between tokens.
- The use of `=>` as an operator name is deprecated. It may be disallowed altogether in a future release.

The operator `!=` is mapped to `<>` on input, so these two names are always equivalent.

At least one of `LEFTARG` and `RIGHTARG` must be defined. For binary operators, both must be defined. For right unary operators, only `LEFTARG` should be defined, while for left unary operators only `RIGHTARG` should be defined.

Note: Right unary, also called postfix, operators are deprecated and may be removed in a future WarehousePG release.

The function_name function must have been previously defined using `CREATE FUNCTION`, must be `IMMUTABLE`, and must be defined to accept the correct number of arguments (either one or two) of the indicated types.

In the syntax of `CREATE OPERATOR`, the keywords `FUNCTION` and `PROCEDURE` are equivalent, but the referenced function must in any case be a function, not a procedure. The use of the keyword `PROCEDURE` here is historical and deprecated.

The other clauses specify optional operator optimization clauses. Their meaning is detailed in the PostgreSQL Operator Optimization Information documentation.

To be able to create an operator, you must have `USAGE` privilege on the argument types and the return type, as well as `EXECUTE` privilege on the underlying function. If a commutator or negator operator is specified, you must own these operators.

Parameters

name The (optionally schema-qualified) name of the operator to be defined. Refer to the *Description* above for allowable characters. The name can be schema-qualified, for example `CREATE OPERATOR myschema.+ (...)`. If not, then the operator is created in the current schema. Two operators in the same schema can have the same name if they operate on different data types. This is called *overloading*.

function_name The function used to implement this operator (must be an `IMMUTABLE` function).

left_type The data type of the operator's left operand, if any. This option would be omitted for a left-unary operator.

right_type The data type of the operator's right operand, if any. This option would be omitted for a right-unary operator.

com_op The commutator of this operator. The optional `COMMUTATOR` clause names an operator that is the commutator of the operator being defined. We say that operator A is the commutator of operator B if (x A y) equals (y B x) for all possible input values x, y. Notice that B is also the commutator of A. For example, operators `<` and `>` for a particular data type are usually each others commutators, and operator + is usually commutative with itself. But operator `-` is usually not commutative with anything. The left operand type of a commutable operator is the same as the right operand type of its commutator, and vice versa. So the name of the commutator operator is all that needs to be provided in the `COMMUTATOR` clause.

neg_op The negator of this operator. The optional `NEGATOR` clause names an operator that is the negator of the operator being defined. We say that operator A is the negator of operator B if both return Boolean results and (x A y) equals NOT (x B y) for all possible inputs x, y. Notice that B is also the negator of A. For example, `<` and `>=` are a negator pair for most data types. An operator's negator must have the same left and/or right operand types as the operator to be defined, so only the operator name need be given in the `NEGATOR` clause.

res_proc The restriction selectivity estimator function for this operator. The optional `RESTRICT` names a restriction selectivity estimation function for the operator. (Note that this is a function name, not an operator name.) `RESTRICT` clauses only make sense for binary operators that return `boolean`.

join_proc The join selectivity estimator function for this operator. The optional `JOIN` clause names a join selectivity estimation function for the operator. (Note that this is a function name, not an operator name.) `JOIN` clauses only make sense for binary operators that return `boolean`.

HASHES Indicates this operator can support a hash join. The optional `HASHES` clause tells the system that it is permissible to use the hash join method for a join based on this operator. `HASHES` only makes sense for a binary operator that returns `boolean`. The hash join operator can only return true for pairs of left and right values that hash to the same hash code. If two values are put in different hash buckets, the join will never compare them, implicitly assuming that the result of the join operator must be false. Because of this, it never makes sense to specify `HASHES` for operators that do not represent equality.

MERGES Indicates this operator can support a merge join. The `MERGES` clause, if present, tells the system that it is permissible to use the merge-join method for a join based on this operator. `MERGES` only makes sense for a binary operator that returns `boolean`, and in practice the operator must represent equality for some data type or pair of data types.

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To give a schema-qualified operator name in com_op or the other optional arguments, use the `OPERATOR()` syntax, for example:

```
COMMUTATOR = OPERATOR(myschema.===) ,
```

Notes

Refer to User-defined Operators in the PostgreSQL documentation for further information.

Any functions used to implement the operator must be defined as `IMMUTABLE`.

It is not possible to specify an operator's lexical precedence in `CREATE OPERATOR`, because the parser's precedence behavior is hard-wired. See Operator Precedence in the PostgreSQL documentation for precedence details.

Use DROP OPERATOR to delete user-defined operators from a database. Use ALTER OPERATOR to modify operators in a database.

Examples

The following command defines a new operator, area-equality, for the data type `box`:

```
CREATE OPERATOR === (
    LEFTARG = box,
    RIGHTARG = box,
    FUNCTION = area_equal_function,
    COMMUTATOR = ===,
    NEGATOR = !==,
    RESTRICT = area_restriction_function,
    JOIN = area_join_function,
    HASHES, MERGES
);
```

The following example creates an operator for adding two complex numbers. The example assumes that we have already created the definition of type `complex`. First define the function that does the work, then define the operator:

```
CREATE FUNCTION complex_add(complex, complex)
    RETURNS complex
    AS 'filename', 'complex_add'
    LANGUAGE C IMMUTABLE STRICT;
CREATE OPERATOR + (
    leftarg = complex,
    rightarg = complex,
    procedure = complex_add,
    commutator = +
);
```

To use this operator in a query:

```
SELECT (a + b) AS c FROM test_complex;
```

Compatibility

`CREATE OPERATOR` is a WarehousePG extension to the SQL standard. The SQL standard does not provide for user-defined operators.

See Also

CREATE FUNCTION, CREATE TYPE, ALTER OPERATOR, CREATE OPERATOR CLASS, DROP OPERATOR

Parent topic: SQL Commands

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7.1.67 CREATE OPERATOR CLASS

Defines a new operator class.

Synopsis

```
CREATE OPERATOR CLASS <name> [DEFAULT] FOR TYPE <data_type>
  USING <index_method> [ FAMILY <family_name> ] AS
  { OPERATOR <strategy_number> <operator_name> [ ( <op_type>, <op_type> ) ] [ FOR SEARCH | FOR ORDER BY <sort_family_name> ]
  | FUNCTION <support_number> [ ( <op_type> [ , <op_type> ] ) ] <function_name> (<argument_type> [, ...] )
  | STORAGE <storage_type>
  } [, ... ]
```

Description

`CREATE OPERATOR CLASS` creates a new operator class. An operator class defines how a particular data type can be used with an index. The operator class specifies that certain operators will fill particular roles or strategies for this data type and this index method. The operator class also specifies the support functions to be used by the index method when the operator class is selected for an index column. All of the operators and functions used by an operator class must be defined before the operator class is created. Any functions used to implement the operator class must be defined as `IMMUTABLE`.

If a schema name is given, then the operator class is created in the specified schema. Otherwise, it is created in the current schema. Two operator classes in the same schema can have the same name only if they are for different index methods.

The user who defines an operator class becomes its owner. Presently, the creating user must be a superuser. (This restriction is made because an erroneous operator class definition could confuse or even crash the server.)

`CREATE OPERATOR CLASS` does not presently check whether the operator class definition includes all the operators and functions required by the index method, nor whether the operators and functions form a self-consistent set. It is the user's responsibility to define a valid operator class.

Related operator classes can be grouped into operator families. To add a new operator class to an existing family, specify the `FAMILY` option in `CREATE OPERATOR CLASS`. Without this option, the new class is placed into a family named the same as the new class (WarehousePG creates that family if it doesn't already exist).

Refer to Interfacing Extensions to Indexes in the PostgreSQL documentation for more information.

Parameters

name The (optionally schema-qualified) name of the operator class to be defined. Two operator classes in the same schema can have the same name only if they are for different index methods.

DEFAULT If present, makes the operator class the default operator class for its data type. At most one operator class can be the default for a specific data type and index method.

data_type The column data type that this operator class is for.

index_method The name of the index method that this operator class is for.

family_name The name of the existing operator family to add this operator class to. If not specified, a family named the same as the operator class is used (creating it, if it doesn't already exist).

strategy_number The index method's strategy number for an operator associated with the operator class. The operators associated with an operator class are identified by *strategy numbers*, which serve to identify the semantics of each operator within the context of its operator class.

operator_name The name (optionally schema-qualified) of an operator associated with the operator class.

op_type In an `OPERATOR` clause, the operand data type(s) of the operator, or `NONE` to signify a left-unary or right-unary operator. The operand data types can be omitted in the normal case where they are the same as the operator class's data type.

In a `FUNCTION` clause, the operand data type(s) the function is intended to support, if different from the input data type(s) of the function (for B-tree comparison functions and hash functions) or the class's data type (for B-tree sort support functions and all functions in GiST, SP-GiST, GIN, and BRIN operator classes). These defaults are correct, and so op_type need not be specified in `FUNCTION` clauses, except for the case of a B-tree sort support function that is meant to support cross-data-type comparisons.

sort_family_name The name (optionally schema-qualified) of an existing `btree` operator family that describes the sort ordering associated with an ordering operator.

If neither `FOR SEARCH` nor `FOR ORDER BY` is specified, `FOR SEARCH` is the default.

support_number The index method's support function number for a function associated with the operator class.

function_name The name (optionally schema-qualified) of a function that is an index method support function for the operator class.

argument_type The parameter data type(s) of the function.

storage_type The data type actually stored in the index. Normally this is the same as the column data type, but some index methods (currently GiST, GIN, and BRIN) allow it to be different. The `STORAGE` clause must be omitted unless the index method allows a different type to be used. If the column data_type is specified as `anyarray`, the storage_type can be declared as `anyelement` to indicate that the index entries are members of the element type belonging to the actual array type that each particular index is created for.

The `OPERATOR`, `FUNCTION`, and `STORAGE` clauses can appear in any order.

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Notes

Because the index machinery does not check access permissions on functions before using them, including a function or operator in an operator class is the same as granting public execute permission on it. This is usually not an issue for the sorts of functions that are useful in an operator class.

The operators should not be defined by SQL functions. A SQL function is likely to be inlined into the calling query, which will prevent the optimizer from recognizing that the query matches an index.

Any functions used to implement the operator class must be defined as `IMMUTABLE`.

Before WarehousePG 6.0, the `OPERATOR` clause could include a `RECHECK` option. This option is no longer supported. WarehousePG now determines whether an index operator is "lossy" on-the-fly at run time. This allows more efficient handling of cases where an operator might or might not be lossy.

Examples

The following example command defines a GiST index operator class for the data type `_int4` (array of int4). See the `intarray` contrib module for the complete example.

```
CREATE OPERATOR CLASS gist__int_ops
    DEFAULT FOR TYPE _int4 USING gist AS
        OPERATOR 3 &&,
        OPERATOR 6 = (anyarray, anyarray),
        OPERATOR 7 @>,
        OPERATOR 8 <@,
        OPERATOR 20 @@ (_int4, query_int),
        FUNCTION 1 g_int_consistent (internal, _int4, smallint, oid, internal),
        FUNCTION 2 g_int_union (internal, internal),
        FUNCTION 3 g_int_compress (internal),
        FUNCTION 4 g_int_decompress (internal),
        FUNCTION 5 g_int_penalty (internal, internal, internal),
        FUNCTION 6 g_int_picksplit (internal, internal),
        FUNCTION 7 g_int_same (_int4, _int4, internal);
```

Compatibility

`CREATE OPERATOR CLASS` is a WarehousePG extension. There is no `CREATE OPERATOR CLASS` statement in the SQL standard.

See Also

ALTER OPERATOR CLASS, DROP OPERATOR CLASS, CREATE OPERATOR FAMILY, ALTER OPERATOR FAMILY, CREATE FUNCTION

Parent topic: SQL Commands

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7.1.68 CREATE OPERATOR FAMILY

Defines a new operator family.

Synopsis

```
CREATE OPERATOR FAMILY <name>  USING <index_method>
```

Description

`CREATE OPERATOR FAMILY` creates a new operator family. An operator family defines a collection of related operator classes, and perhaps some additional operators and support functions that are compatible with these operator classes but not essential for the functioning of any individual index. (Operators and functions that are essential to indexes should be grouped within the relevant operator class, rather than being "loose" in the operator family. Typically, single-data-type operators are bound to operator classes, while cross-data-type operators can be loose in an operator family containing operator classes for both data types.)

The new operator family is initially empty. It should be populated by issuing subsequent `CREATE OPERATOR CLASS` commands to add contained operator classes, and optionally `ALTER OPERATOR FAMILY` commands to add "loose" operators and their corresponding support functions.

If a schema name is given then the operator family is created in the specified schema. Otherwise it is created in the current schema. Two operator families in the same schema can have the same name only if they are for different index methods.

The user who defines an operator family becomes its owner. Presently, the creating user must be a superuser. (This restriction is made because an erroneous operator family definition could confuse or even crash the server.)

Refer to Interfacing Extensions to Indexes in the PostgreSQL documentation for more information.

Parameters

name The (optionally schema-qualified) name of the operator family to be created.

index_method The name of the index method this operator family is for.

Compatibility

`CREATE OPERATOR FAMILY` is a WarehousePG extension. There is no `CREATE OPERATOR FAMILY` statement in the SQL standard.

See Also

ALTER OPERATOR FAMILY, DROP OPERATOR FAMILY, ALTER OPERATOR CLASS, CREATE OPERATOR CLASS, DROP OPERATOR CLASS

Parent topic: SQL Commands

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7.1.69 CREATE POLICY

Defines a new row-level security policy for a table.

Synopsis

```
CREATE POLICY <name> ON <table_name>
    [ AS { PERMISSIVE | RESTRICTIVE } ]
    [ FOR { ALL | SELECT | INSERT | UPDATE | DELETE } ]
    [ TO { <role_name> | PUBLIC | CURRENT_USER | SESSION_USER } [, ...] ]
    [ USING ( <using_expression> ) ]
    [ WITH CHECK ( <check_expression> ) ]
```

Description

The `CREATE POLICY` command defines a new row-level security policy for a table. Note that row-level security must be enabled on the table (using `ALTER TABLE ... ENABLE ROW LEVEL SECURITY`) in order for WarehousePG to apply created policies.

A policy grants the permission to select, insert, update, or delete rows that match the relevant policy expression. Existing table rows are checked against the expression specified in `USING`, while new rows that would be created via `INSERT` or `UPDATE` are checked against the expression specified in `WITH CHECK`. When a `USING` expression returns true for a given row, then that row is visible to the user, while if false or null is returned then the row is not visible. When a `WITH CHECK` expression returns true for a row, then that row is inserted or updated, while if false or null is returned then an error occurs.

For `INSERT` and `UPDATE` statements, `WITH CHECK` expressions are enforced before any actual data modifications are made, and before any other constraints.

Policy names are per-table. Therefore, one policy name can be used for many different tables and have a definition for each table which is appropriate to that table.

Policies can be applied for specific commands or for specific roles. The default for newly-created policies is that they apply for all commands and roles, unless otherwise specified. Multiple policies may apply to a single command; see below for more details. The table in Per-Command Policies summarizes how the different types of policies apply to specific commands.

For policies that can have both `USING` and `WITH CHECK` expressions (`ALL` and `UPDATE`), if no `WITH CHECK` expression is defined, then the `USING` expression will be used both to determine which rows are visible (normal `USING` case) and which new rows will be allowed to be added (`WITH CHECK` case).

If row-level security is enabled for a table, but no applicable policies exist, a "default deny" policy is assumed, so that no rows will be visible or updatable.

Parameters

name The name of the policy to be created. This must be distinct from the name of any other policy defined for the table.

table_name The name (optionally schema-qualified) of the table to which the policy applies.

PERMISSIVE Specify that the policy is to be created as a permissive policy. All permissive policies which are applicable to a given query will be combined together using the Boolean `OR` operator. By creating permissive policies, administrators can add to the set of records which can be accessed. Policies are permissive by default.

RESTRICTIVE Specify that the policy is to be created as a restrictive policy. All restrictive policies which are applicable to a given query will be combined together using the Boolean `AND` operator. By creating restrictive policies, administrators can reduce the set of records which can be accessed as all restrictive policies must be passed for each record.

You must define at least one permissive policy to grant access to records before restrictive policies can be usefully used to reduce that access. If only restrictive policies exist, then no records will be accessible. When a mix of permissive and restrictive policies are present, a record is only accessible if at least one of the permissive policies passes, in addition to all the restrictive policies.

command The command to which the policy applies. Valid options are `ALL`, `SELECT`, `INSERT`, `UPDATE`, and `DELETE`. `ALL` is the default. See below for specifics regarding how these are applied.

role_name The role(s) to which the policy is to be applied. The default is `PUBLIC`, which will apply the policy to all roles.

using_expression Any SQL conditional expression (returning `boolean`). The conditional expression cannot contain any aggregate or window functions. This expression will be added to queries that refer to the table if row-level security is enabled. Rows for which the expression returns true will be visible. Any rows for which the expression returns false or null will not be visible to the user (in a `SELECT`), and will not be available for modification (in an `UPDATE` or `DELETE`). Such rows are silently suppressed; no error is reported.

check_expression Any SQL conditional expression (returning `boolean`). The conditional expression cannot contain any aggregate or window functions. This expression will be used in `INSERT` and `UPDATE` queries against the table if row-level security is enabled. Only rows for which the expression evaluates to true will be allowed. An error will be thrown if the expression evaluates to false or null for any of the records inserted or any of the records that result from the update. Note that the check_expression is evaluated against the proposed new contents of the row, not the original contents.

Per-Command Policies

ALL Using `ALL` for a policy means that it will apply to all commands, regardless of the type of command. If an `ALL` policy exists and more specific policies exist, then both the `ALL` policy and the more specific policy (or policies) will be applied. Additionally, `ALL` policies will be applied to both the selection side of a query and the modification side, using the `USING` expression for both cases if only a `USING` expression has been defined.

As an example, if an `UPDATE` is issued, then the `ALL` policy will be applicable both to what the `UPDATE` will be able to select as rows to be updated (applying the `USING` expression), and to the resulting updated rows, to check if they are permitted to be added to the table (applying the `WITH CHECK` expression, if defined, and the `USING` expression otherwise). If an `INSERT` or `UPDATE` command attempts to add rows to the table that do not pass the `ALL` policy's `WITH CHECK` expression, the entire command will be aborted.

SELECT Using `SELECT` for a policy means that it will apply to `SELECT` queries and whenever `SELECT` permissions are required on the relation that the policy is defined for. The result is that only those records from the relation that pass the `SELECT` policy will be returned during a `SELECT` query, and that queries that require `SELECT` permissions, such as `UPDATE`, will also only see those records that are allowed by the `SELECT` policy. A `SELECT` policy cannot have a `WITH CHECK` expression, as it only applies in cases where records are being retrieved from the relation.

INSERT Using `INSERT` for a policy means that it will apply to `INSERT` commands. Rows being inserted that do not pass this policy will result in a policy violation error, and the entire `INSERT` command will be aborted. An `INSERT` policy cannot have a `USING` expression, as it only applies in cases where records are being added to the relation.

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Note that `INSERT` with `ON CONFLICT DO UPDATE` checks `INSERT` policies' `WITH CHECK` expressions only for rows appended to the relation by the `INSERT` path.

UPDATE Using `UPDATE` for a policy means that it will apply to `UPDATE`, `SELECT FOR UPDATE`, and `SELECT FOR SHARE` commands, as well as auxiliary `ON CONFLICT DO UPDATE` clauses of `INSERT` commands. Since `UPDATE` involves pulling an existing record and replacing it with a new modified record, `UPDATE` policies accept both a `USING` expression and a `WITH CHECK` expression. The `USING` expression determines which records the `UPDATE` command will see to operate against, while the `WITH CHECK` expression defines which modified rows are allowed to be stored back into the relation.

Any rows whose updated values do not pass the `WITH CHECK` expression will cause an error, and the entire command will be aborted. If only a `USING` clause is specified, then that clause will be used for both `USING` and `WITH CHECK` cases.

Typically an `UPDATE` command also needs to read data from columns in the relation being updated (e.g., in a `WHERE` clause or a `RETURNING` clause, or in an expression on the right hand side of the `SET` clause). In this case, `SELECT` rights are also required on the relation being updated, and the appropriate `SELECT` or `ALL` policies will be applied in addition to the `UPDATE` policies. Thus the user must have access to the row(s) being updated through a `SELECT` or `ALL` policy in addition to being granted permission to update the row(s) via an `UPDATE` or `ALL` policy.

When an `INSERT` command has an auxiliary `ON CONFLICT DO UPDATE` clause, if the `UPDATE` path is taken, the row to be updated is first checked against the `USING` expressions of any `UPDATE` policies, and then the new updated row is checked against the `WITH CHECK` expressions. Note, however, that unlike a standalone `UPDATE` command, if the existing row does not pass the `USING` expressions, an error will be thrown (the `UPDATE` path will never be silently avoided).

DELETE Using `DELETE` for a policy means that it will apply to `DELETE` commands. Only rows that pass this policy will be seen by a `DELETE` command. There can be rows that are visible through a `SELECT` that are not available for deletion, if they do not pass the `USING` expression for the `DELETE` policy.

In most cases a `DELETE` command also needs to read data from columns in the relation that it is deleting from (e.g., in a `WHERE` clause or a `RETURNING` clause). In this case, `SELECT` rights are also required on the relation, and the appropriate `SELECT` or `ALL` policies will be applied in addition to the `DELETE` policies. Thus the user must have access to the row(s) being deleted through a `SELECT` or `ALL` policy in addition to being granted permission to delete the row(s) via a `DELETE` or `ALL` policy.

A `DELETE` policy cannot have a `WITH CHECK` expression, as it only applies in cases where records are being deleted from the relation, so that there is no new row to check.

Command	SELECT/ALL policy USING expresson	INSERT/ALL policy WITH CHECK expression	UPDATE/ALL policy USING expression	UPDATE/ALL policy WITH CHECK expression	DELETE/ALL policy USING expression
SELECT	Existing row	--	--	--	--
SELECT FOR UPDATE/SHARE	Existing row	--	Existing row	--	--
INSERT	--	New row	--	--	--
INSERT ... RETURNING	New row[a]	New row	--	--	--
UPDATE	Existing and new rows[a]	--	Existing row	New row	--
DELETE	Existing row[a]	--	--	--	Existing row
ON CONFLICT DO UPDATE	Existing and new rows	--	Existing row	New row	--

[a]If read access is required to the existing or new row (for example, a `WHERE` or `RETURNING` clause that refers to columns from the relation).

Application of Multiple Policies

When multiple policies of different command types apply to the same command (for example, `SELECT` and `UPDATE` policies applied to an `UPDATE` command), then the user must have both types of permissions (for example, permission to select rows from the relation as well as permission to update them). Thus the expressions for one type of policy are combined with the expressions for the other type of policy using the `AND` operator.

When multiple policies of the same command type apply to the same command, then there must be at least one `PERMISSIVE` policy granting access to the relation, and all of the `RESTRICTIVE` policies must pass. Thus all the `PERMISSIVE` policy expressions are combined using `OR`, all the `RESTRICTIVE` policy expressions are combined using `AND`, and the results are combined using `AND`. If there are no `PERMISSIVE` policies, then access is denied.

Note that, for the purposes of combining multiple policies, `ALL` policies are treated as having the same type as whichever other type of policy is being applied.

For example, in an `UPDATE` command requiring both `SELECT` and `UPDATE` permissions, if there are multiple applicable policies of each type, they will be combined as follows:

```
expression from RESTRICTIVE SELECT/ALL policy 1
AND
expression from RESTRICTIVE SELECT/ALL policy 2
AND
...
AND
(
  expression from PERMISSIVE SELECT/ALL policy 1
  OR
  expression from PERMISSIVE SELECT/ALL policy 2
  OR
  ...
)
AND
expression from RESTRICTIVE UPDATE/ALL policy 1
AND
expression from RESTRICTIVE UPDATE/ALL policy 2
AND
...
AND
(
  expression from PERMISSIVE UPDATE/ALL policy 1
  OR
  expression from PERMISSIVE UPDATE/ALL policy 2
  OR
  ...
)
```

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Notes

You must be the owner of a table to create or change policies for it.

While policies will be applied for explicit queries against tables in the database, they are not applied when the system is performing internal referential integrity checks or validating constraints. This means there are indirect ways to determine that a given value exists. An example of this is attempting to insert a duplicate value into a column that is a primary key or has a unique constraint. If the insert fails then the user can infer that the value already exists. (This example assumes that the user is permitted by policy to insert records which they are not allowed to see.) Another example is where a user is allowed to insert into a table which references another, otherwise hidden table. Existence can be determined by the user inserting values into the referencing table, where success would indicate that the value exists in the referenced table. These issues can be addressed by carefully crafting policies to prevent users from being able to insert, delete, or update records at all which might possibly indicate a value they are not otherwise able to see, or by using generated values (e.g., surrogate keys) instead of keys with external meanings.

Generally, the system will enforce filter conditions imposed using security policies prior to qualifications that appear in user queries, in order to prevent inadvertent exposure of the protected data to user-defined functions which might not be trustworthy. However, functions and operators marked by the system (or the system administrator) as `LEAKPROOF` may be evaluated before policy expressions, as they are assumed to be trustworthy.

Since policy expressions are added to the user's query directly, they will be run with the rights of the user running the overall query. Therefore, users who are using a given policy must be able to access any tables or functions referenced in the expression or they will simply receive a permission denied error when attempting to query the table that has row-level security enabled. This does not change how views work, however. As with normal queries and views, permission checks and policies for the tables which are referenced by a view will use the view owner's rights and any policies which apply to the view owner.

Refer to About Configuring Row-Level Security Policies for more information and practical examples.

Compatibility

`CREATE POLICY` is a WarehousePG extension to the SQL standard.

See Also

ALTER POLICY, DROP POLICY, ALTER TABLE

Parent topic: SQL Commands

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7.1.70 CREATE PROCEDURE

Defines a new procedure.

Synopsis

```
CREATE [OR REPLACE] PROCEDURE <name>
    ( [ [<argmode>] [<argname>] <argtype> [ { DEFAULT | = } <default_expr> ] [, ...] ] )
  { LANGUAGE <lang_name>
    | TRANSFORM { FOR TYPE <type_name> } [, ... ]
    | { [ EXTERNAL ] SECURITY INVOKER | [ EXTERNAL ] SECURITY DEFINER }
    | SET <configuration_parameter> { TO <value> | = <value> | FROM CURRENT }
    | AS '<definition>'
    | AS '<obj_file>', '<link_symbol>'
  } ...
```

Description

`CREATE PROCEDURE` defines a new procedure. `CREATE OR REPLACE PROCEDURE` either creates a new procedure, or replaces an existing definition. To define a procedure, the user must have the `USAGE` privilege on the language.

If a schema name is included, then the procedure is created in the specified schema. Otherwise it is created in the current schema. The name of the new procedure must not match any existing procedure with the same input argument types in the same schema. However, procedures and functions of different argument types may share a name (overloading).

To update the current definition of an existing procedure, use `CREATE OR REPLACE PROCEDURE`. It is not possible to change the name or argument types of a procedure this way (this would actually create a new, distinct procedure).

When `CREATE OR REPLACE PROCEDURE` is used to replace an existing procedure, the ownership and permissions of the procedure do not change. All other procedure properties are assigned the values specified or implied in the command. You must own the procedure to replace it (this includes being a member of the owning role).

The user that creates the procedure becomes the owner of the procedure.

To be able to create a procedure, you must have `USAGE` privilege on the argument types.

For more information about creating procedures, refer to the User Defined Procedures section of the PostgreSQL documentation.

Parameters

name The name (optionally schema-qualified) of the procedure to create.

argmode The mode of an argument: either `IN`, `INOUT`, or `VARIADIC`. If omitted, the default is `IN`. (`OUT` arguments are currently not supported for procedures. Use `INOUT` instead.)

argname The name of an argument.

argtype The data type(s) of the procedure's arguments (optionally schema-qualified), if any. The argument types may be base, composite, or domain types, or may reference the type of a table column.

Depending on the implementation language it may also be allowed to specify pseudotypes such as `cstring`. Pseudotypes indicate that the actual argument type is either incompletely specified, or outside the set of ordinary SQL data types.

The type of a column is referenced by writing `table_name.column_name%TYPE`. Using this feature can sometimes help make a procedure independent of changes to the definition of a table.

default_expr An expression to be used as the default value if the parameter is not specified. The expression must be coercible to the argument type of the parameter. Each input parameter in the argument list that follows a parameter with a default value must have a default value as well.

lang_name The name of the language that the procedure is implemented in. May be `SQL`, `C`, `internal`, or the name of a user-defined procedural language, e.g. `plpgsql`. Enclosing the name in single quotes is deprecated and requires matching case.

TRANSFORM { FOR TYPE type_name } [, ...] } Lists which transforms a call to the procedure should apply. Transforms convert between SQL types and language-specific data types. Procedural language implementations usually have hardcoded knowledge of the built-in types, so those don't need to be listed here. If a procedural language implementation does not know how to handle a type and no transform is supplied, it will fall back to a default behavior for converting data types, but this depends on the implementation.

[EXTERNAL] SECURITY INVOKER [EXTERNAL] SECURITY DEFINER `SECURITY INVOKER` (the default) indicates that the procedure is to be run with the privileges of the user that calls it. `SECURITY DEFINER` specifies that the procedure is to be run with the privileges of the user that created it. The key word `EXTERNAL` is allowed for SQL conformance, but it is optional since, unlike in SQL, this feature applies to all procedures not just external ones. A `SECURITY DEFINER` procedure cannot execute transaction control statements (for example, `COMMIT` and `ROLLBACK`, depending on the language).

configuration_parameter value The `SET` clause applies a value to a session configuration parameter when the procedure is entered. The configuration parameter is restored to its prior value when the procedure exits. `SET FROM CURRENT` saves the value of the parameter that is current when `CREATE PROCEDURE` is run as the value to be applied when the procedure is entered. If a `SET` clause is attached to a procedure, then the effects of a `SET LOCAL` command executed inside the procedure for the same variable are restricted to the procedure: the configuration parameter's prior value is still restored at procedure exit. However, an ordinary `SET` command (without `LOCAL`) overrides the `SET` clause, much as it would do for a previous `SET LOCAL` command: the effects of such a command will persist after procedure exit, unless the current transaction is rolled back. If a `SET` clause is attached to a procedure, then that procedure cannot execute transaction control statements (for example, `COMMIT` and `ROLLBACK`, depending on the language). See SET for more information about allowed parameter names and values.

definition A string constant defining the procedure; the meaning depends on the language. It may be an internal procedure name, the path to an object file, an SQL command, or text in a procedural language.

It is often helpful to use dollar quoting (refer to Dollar-Quoted String Constants in the PostgreSQL documentation) to write the procedure definition string, rather than the normal single quote syntax. Without dollar quoting, any single quotes or backslashes in the procedure definition must be escaped by doubling them.

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obj_file, link_symbol This form of the `AS` clause is used for dynamically loadable C language procedures when the procedure name in the C language source code is not the same as the name of the SQL procedure. The string obj_file is the name of the file containing the dynamically loadable object, and is interpreted as for the LOAD command. The string link_symbol is the name of the procedure in the C language source code. If the link symbol is omitted, it is assumed to be the same as the name of the SQL procedure being defined. When repeated `CREATE PROCEDURE` calls refer to the same object file, the file is only loaded once per session. To unload and reload the file (perhaps during development), start a new session.

Notes

See CREATE FUNCTION for more details on function creation that also apply to procedures.

Use CALL to execute a procedure.

Examples

```
CREATE PROCEDURE insert_data(a integer, b integer)
LANGUAGE SQL
AS $$
INSERT INTO tbl VALUES (a);
INSERT INTO tbl VALUES (b);
$$;

CALL insert_data(1, 2);
```

Compatibility

A `CREATE PROCEDURE` command is defined in the SQL standard. The WarehousePG version is similar but not fully compatible. For details see also CREATE FUNCTION.

See Also

ALTER PROCEDURE, DROP PROCEDURE, CREATE FUNCTION, CALL

Parent topic: SQL Commands

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7.1.71 CREATE PROTOCOL

Registers a custom data access protocol that can be specified when defining a WarehousePG external table.

Synopsis

```
CREATE [TRUSTED] PROTOCOL <name> (
   [readfunc='<read_call_handler>'] [, writefunc='<write_call_handler>']
   [, validatorfunc='<validate_handler>' ])
```

Description

`CREATE PROTOCOL` associates a data access protocol name with call handlers that are responsible for reading from and writing data to an external data source. You must be a superuser to create a protocol.

The `CREATE PROTOCOL` command must specify either a read call handler or a write call handler. The call handlers specified in the `CREATE PROTOCOL` command must be defined in the database.

The protocol name can be specified in a `CREATE EXTERNAL TABLE` command.

For information about creating and enabling a custom data access protocol, refer to the Example Custom Data Access Protocol documentation.

Parameters

TRUSTED If not specified, only superusers and the protocol owner can create external tables using the protocol. If specified, superusers and the protocol owner can `GRANT` permissions on the protocol to other database roles.

name The name of the data access protocol. The protocol name is case sensitive. The name must be unique among the protocols in the database.

readfunc= 'read_call_handler' The name of a previously registered function that WarehousePG calls to read data from an external data source. The command must specify either a read call handler or a write call handler.

writefunc= 'write_call_handler' The name of a previously registered function that WarehousePG calls to write data to an external data source. The command must specify either a read call handler or a write call handler.

validatorfunc='validate_handler' An optional validator function that validates the URL specified in the `CREATE EXTERNAL TABLE` command.

Notes

WarehousePG handles external tables of type `file`, `gpfdist`, and `gpfdists` internally. See s3:// Protocol for information about enabling the `S3` protocol. Refer to pxf:// Protocol for information about using the `pxf` protocol.

Any shared library that implements a data access protocol must be located in the same location on all WarehousePG segment hosts. For example, the shared library can be in a location specified by the operating system environment variable `LD_LIBRARY_PATH` on all hosts. You can also specify the location when you define the handler function. For example, when you define the `s3` protocol in the `CREATE PROTOCOL` command, you specify `$libdir/gps3ext.so` as the location of the shared object, where `$libdir` is located at `$GPHOME/lib`.

Compatibility

`CREATE PROTOCOL` is a WarehousePG extension.

See Also

ALTER PROTOCOL, CREATE EXTERNAL TABLE, DROP PROTOCOL, GRANT

Parent topic: SQL Commands

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7.1.72 CREATE RESOURCE GROUP

Defines a new resource group.

Synopsis

```
CREATE RESOURCE GROUP <name> WITH (<group_attribute>=<value> [, ... ])
```

where group_attribute is one of:

```
[ CONCURRENCY=<integer> ]
CPU_MAX_PERCENT=<integer> | CPUSET=<coordinator_cores>;<segment_cores>
[ CPU_WEIGHT=<integer> ]
[ MEMORY_QUOTA=<integer> ]
[ MIN_COST=<integer> ]
[ IO_LIMIT=' <tablespace_io_limit_spec> [; ...] ' ]
```

Where `<tablespace_io_limit_spec>` is:

```
<tablespace_name> | <oid> : <io_limit_option_spec> [, ...]
```

Where `<io_limit_option_spec>` is:

```
wbps=<io_limit_option_value>
| rbps=<io_limit_option_value>
| wiops=<io_limit_option_value>
| riops=<io_limit_option_value>
```

Where `<io_limit_option_vlaue>` is:

```
<integer> | max
```

Description

Creates a new resource group for WarehousePG resource management. You can create resource groups to manage resources for roles or to manage the resources of a WarehousePG external component such as PL/Container.

A resource group that you create to manage a user role identifies concurrent transaction, memory, CPU, and disk I/O limits for the role when resource groups are enabled. You may assign such resource groups to one or more roles.

A resource group that you create to manage the resources of a WarehousePG external component such as PL/Container identifies the CPU limits for the component when resource groups are enabled. These resource groups use cgroups for both CPU management. Assignment of resource groups to external components is component-specific. For example, you assign a PL/Container resource group when you configure a PL/Container runtime. You cannot assign a resource group that you create for external components to a role, nor can you assign a resource group that you create for roles to an external component.

You must have `SUPERUSER` privileges to create a resource group. The maximum number of resource groups allowed in your WarehousePG cluster is 100.

WarehousePG pre-defines three default resource groups: `admin_group`, `default_group`, and `system_group`. These group names, as well as the group name `none`, are reserved.

To set appropriate limits for resource groups, the WarehousePG administrator must be familiar with the queries typically run on the system, as well as the users/roles running those queries and the external components they may be using, such as PL/Containers

After creating a resource group for a role, assign the group to one or more roles using the ALTER ROLE or CREATE ROLE commands.

After you create a resource group to manage the CPU resources of an external component, configure the external component to use the resource group. For example, configure the PL/Container runtime `resource_group_id`.

Parameters

name The name of the resource group.

CONCURRENCY integer Optional. The maximum number of concurrent transactions, including active and idle transactions, that are permitted for this resource group. The `CONCURRENCY` value must be an integer in the range [0 .. `max_connections`]. The default `CONCURRENCY` value for resource groups defined for roles is 20.

You must set `CONCURRENCY` to `0` for resource groups that you create for external components.

> **Note** You cannot set the `CONCURRENCY` value for the `admin_group` to `0`.

CPU_MAX_PERCENT integer Optional. The percentage of the maximum available CPU resources that the resource group can use. The value range is `1-100`.

CPU_WEIGHT integer Optional. The scheduling priority of the current group. The value range is `1-500`, the default is `100.

CPUSET <coordinator_cores>;<segment_cores>

`CPUSET` identifies the CPU cores to reserve for this resource group on the coordinator host and on segment hosts. The CPU cores that you specify must be available in the system and cannot overlap with any CPU cores that you specify for other resource groups.

> **Note** You must specify either `CPU_MAX_PERCENT` or `CPUSET` when you create a resource group, but not both.

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Specify cores as a comma-separated list of single core numbers or core number intervals. Define the coordinator host cores first, followed by segment host cores, and separate the two with a semicolon. You must enclose the full core configuration in single quotes. For example, '1;1,3-4' configures core 1 for the coordinator host, and cores 1, 3, and 4 for the segment hosts.

> **Note** You can configure `CPUSET` for a resource group only after you have enabled resource group-based resource management for your WarehousePG cluster.

IO_LIMIT='<tablespace_io_limit_spec> [; ...]' Optional. The maximum read/write sequential disk I/O throughput, and the maximum read/write I/O operations per second for the queries assigned to a specific resource group.

Where `<tablespace_io_limit_spec>` is:

```
<tablespace_name> | <oid> : <io_limit_option_spec> [, ...]
```

Where `<io_limit_option_spec>` is:

```
wbps=<io_limit_option_value>
| rbps=<io_limit_option_value>
| wiops=<io_limit_option_value>
| riops=<io_limit_option_value>
```

Where `<io_limit_option_vlaue>` is:

```
<integer> | max
```

When you use this parameter, you may speficy:

- The tablespace name or the tablespace object ID (OID) you set the limits for. Use `*` to set limits for all tablespaces.
- The values for `rbps` and `wbps` to limit the maximum read and write sequential disk I/O throughput in the resource group, in MB/S. The default value is `max`, which means there is no limit.
- The values for `riops` and `wiops` to limit the maximum read and write I/O operations per second in the resource group. The default value is `max`, which means there is no limit.

If the parameter `IO_LIMIT` is not set, the default value for `rbps`, `wpbs`, `riops`, and `wiops` s is set to `max`, which means that there are no disk I/O limits. In this scenario, the `gp_toolkit.gp_resgroup_config` system view displays its value as `-1`.

> **Note** The parameter `IO_LIMIT` is only available when you use Linux Control Groups v2. See Configuring and Using Resource Groups for more information.

MEMORY_QUOTA integer Optional. The maximum available memory, in MB, to reserve for this resource group. This value determines the total amount of memory that all worker processes within a resource group can consume on a segment host during query execution.

The minimum memory quantity you can specify for a resource group is `0`. The default value is `-1`.

When you specify a `MEMORY_QUOTA` of `-1`, `MEMORY_QUOTA` takes the value of the `statement_mem` server configuration parameter.

> **Note** If the server configuration parameter `gp_resgroup_memory_query_fixed_mem` is set, its value overrides at the session level the value of `MEMORY_QUOTA`.

MIN_COST integer Optional. The limit on the cost of the query plan generated by a query in this resource group. When the query plan cost of the query is less than this value, the query will be unassigned from the resource group to which it belongs.

This means that low-cost queries will execute more quickly, as they are not subject to resource constraints.

The value range is `0-500`. The default value is `0`, which means that the cost is not used to bypass the query.

Notes

You cannot submit a `CREATE RESOURCE GROUP` command in an explicit transaction or sub-transaction.

Use the `gp_toolkit.gp_resgroup_config` system view to display the limit settings of all resource groups:

```
SELECT * FROM gp_toolkit.gp_resgroup_config;
```

Examples

Create a resource group with CPU and memory quota of 350 MB:

```
CREATE RESOURCE GROUP rgroup1 WITH (CPU_MAX_PERCENT=35, MEMORY_QUOTA=350);
```

Create a resource group with a concurrent transaction limit of 20, a memory quota of 1500 MB, a CPU limit of 25, and disk I/O limits for the `pg_default` tablespace:

```
CREATE RESOURCE GROUP rgroup2 WITH (CONCURRENCY=20,
  MEMORY_QUOTA=1500, CPU_MAX_PERCENT=25,
  IO_LIMIT='pg_default: wbps=1000, rbps=1000, wiops=100, riops=100');
```

Create a resource group with a concurrent transaction limit of 20, a memory quota of 1500 MB, a CPU limit of 25, and disk I/O limits for a tablespace with oid 1663:

```
CREATE RESOURCE GROUP rgroup2 WITH (CONCURRENCY=20,
  MEMORY_QUOTA=1500, CPU_MAX_PERCENT=25,
  IO_LIMIT='1663: wbps=1000, rbps=1000, wiops=100, riops=100');
```

Create a resource group with a memory quota of 110 MB to which you assign CPU core 1 on the coordinator host, and cores 1 to 3 on segment hosts:

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```
CREATE RESOURCE GROUP rgroup3 WITH (CPUSET='1;1-3', MEMORY_QUOTA=110);
```

Compatibility

`CREATE RESOURCE GROUP` is a WarehousePG extension. There is no provision for resource groups or resource management in the SQL standard.

See Also

ALTER ROLE, CREATE ROLE, ALTER RESOURCE GROUP, DROP RESOURCE GROUP

Parent topic: SQL Commands

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7.1.73 CREATE RESOURCE QUEUE

Defines a new resource queue.

Synopsis

```
CREATE RESOURCE QUEUE <name> WITH (<queue_attribute>=<value> [, ... ])
```

where queue_attribute is:

```
    ACTIVE_STATEMENTS=<integer>
        [ MAX_COST=<float >[COST_OVERCOMMIT={TRUE|FALSE}] ]
        [ MIN_COST=<float >]
        [ PRIORITY={MIN|LOW|MEDIUM|HIGH|MAX} ]
        [ MEMORY_LIMIT='<memory_units>' ]

 | MAX_COST=float [ COST_OVERCOMMIT={TRUE|FALSE} ]
        [ ACTIVE_STATEMENTS=<integer >]
        [ MIN_COST=<float >]
        [ PRIORITY={MIN|LOW|MEDIUM|HIGH|MAX} ]
        [ MEMORY_LIMIT='<memory_units>' ]
```

Description

Creates a new resource queue for WarehousePG resource management. A resource queue must have either an `ACTIVE_STATEMENTS` or a `MAX_COST` value (or it can have both). Only a superuser can create a resource queue.

Resource queues with an `ACTIVE_STATEMENTS` threshold set a maximum limit on the number of queries that can be run by roles assigned to that queue. It controls the number of active queries that are allowed to run at the same time. The value for `ACTIVE_STATEMENTS` should be an integer greater than 0.

Resource queues with a `MAX_COST` threshold set a maximum limit on the total cost of queries that can be run by roles assigned to that queue. Cost is measured in the *estimated total cost* for the query as determined by the query planner (as shown in the `EXPLAIN` output for a query). Therefore, an administrator must be familiar with the queries typically run on the system in order to set an appropriate cost threshold for a queue. Cost is measured in units of disk page fetches; 1.0 equals one sequential disk page read. The value for `MAX_COST` is specified as a floating point number (for example 100.0) or can also be specified as an exponent (for example 1e+2). If a resource queue is limited based on a cost threshold, then the administrator can allow `COST_OVERCOMMIT=TRUE` (the default). This means that a query that exceeds the allowed cost threshold will be allowed to run but only when the system is idle. If `COST_OVERCOMMIT=FALSE` is specified, queries that exceed the cost limit will always be rejected and never allowed to run. Specifying a value for `MIN_COST` allows the administrator to define a cost for small queries that will be exempt from resource queueing.

> **Note** GPORCA and the Postgres-based planner utilize different query costing models and may compute different costs for the same query. The WarehousePG resource queue resource management scheme neither differentiates nor aligns costs between GPORCA and the Postgres-based planner; it uses the literal cost value returned from the optimizer to throttle queries.

When resource queue-based resource management is active, use the `MEMORY_LIMIT` and `ACTIVE_STATEMENTS` limits for resource queues rather than configuring cost-based limits. Even when using GPORCA, WarehousePG may fall back to using the Postgres-based planner for certain queries, so using cost-based limits can lead to unexpected results.

If a value is not defined for `ACTIVE_STATEMENTS` or `MAX_COST`, it is set to `-1` by default (meaning no limit). After defining a resource queue, you must assign roles to the queue using theALTER ROLE or CREATE ROLE command.

You can optionally assign a `PRIORITY` to a resource queue to control the relative share of available CPU resources used by queries associated with the queue in relation to other resource queues. If a value is not defined for `PRIORITY`, queries associated with the queue have a default priority of `MEDIUM`.

Resource queues with an optional `MEMORY_LIMIT` threshold set a maximum limit on the amount of memory that all queries submitted through a resource queue can consume on a segment host. This determines the total amount of memory that all worker processes of a query can consume on a segment host during query execution. WarehousePG recommends that `MEMORY_LIMIT` be used in conjunction with `ACTIVE_STATEMENTS` rather than with `MAX_COST`. The default amount of memory allotted per query on statement-based queues is: `MEMORY_LIMIT / ACTIVE_STATEMENTS`. The default amount of memory allotted per query on cost-based queues is: `MEMORY_LIMIT * (query_cost / MAX_COST)`.

The default memory allotment can be overridden on a per-query basis using the `statement_mem` server configuration parameter, provided that `MEMORY_LIMIT` or `max_statement_mem` is not exceeded. For example, to allocate more memory to a particular query:

```
=> SET statement_mem='2GB';
=> SELECT * FROM my_big_table WHERE column='value' ORDER BY id;
=> RESET statement_mem;
```

The `MEMORY_LIMIT` value for all of your resource queues should not exceed the amount of physical memory of a segment host. If workloads are staggered over multiple queues, memory allocations can be oversubscribed. However, queries can be cancelled during execution if the segment host memory limit specified in `gp_vmem_protect_limit` is exceeded.

For information about `statement_mem`, `max_statement`, and `gp_vmem_protect_limit`, see Server Configuration Parameters.

Parameters

name The name of the resource queue.

ACTIVE_STATEMENTS integer Resource queues with an `ACTIVE_STATEMENTS` threshold limit the number of queries that can be run by roles assigned to that queue. It controls the number of active queries that are allowed to run at the same time. The value for `ACTIVE_STATEMENTS` should be an integer greater than 0.

MEMORY_LIMIT 'memory_units' Sets the total memory quota for all statements submitted from users in this resource queue. Memory units can be specified in kB, MB or GB. The minimum memory quota for a resource queue is 10MB. There is no maximum, however the upper boundary at query execution time is limited by the physical memory of a segment host. The default is no limit (`-1`).

MAX_COST float Resource queues with a `MAX_COST` threshold set a maximum limit on the total cost of queries that can be run by roles assigned to that queue. Cost is measured in the *estimated total cost* for the query as determined by the WarehousePG query optimizer (as shown in the `EXPLAIN` output for a query). Therefore, an administrator must be familiar with the queries typically run on the system in order to set an appropriate cost threshold for a queue. Cost is measured in units of disk page fetches; 1.0 equals one sequential disk page read. The value for `MAX_COST` is specified as a floating point number (for example 100.0) or can also be specified as an exponent (for example 1e+2).

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COST_OVERCOMMIT boolean If a resource queue is limited based on `MAX_COST`, then the administrator can allow `COST_OVERCOMMIT` (the default). This means that a query that exceeds the allowed cost threshold will be allowed to run but only when the system is idle. If `COST_OVERCOMMIT=FALSE` is specified, queries that exceed the cost limit will always be rejected and never allowed to run.

MIN_COST float The minimum query cost limit of what is considered a small query. Queries with a cost under this limit will not be queued and run immediately. Cost is measured in the *estimated total cost* for the query as determined by the query planner (as shown in the `EXPLAIN` output for a query). Therefore, an administrator must be familiar with the queries typically run on the system in order to set an appropriate cost for what is considered a small query. Cost is measured in units of disk page fetches; 1.0 equals one sequential disk page read. The value for `MIN_COST` is specified as a floating point number (for example 100.0) or can also be specified as an exponent (for example 1e+2).

PRIORITY={MIN|LOW|MEDIUM|HIGH|MAX} Sets the priority of queries associated with a resource queue. Queries or statements in queues with higher priority levels will receive a larger share of available CPU resources in case of contention. Queries in low-priority queues may be delayed while higher priority queries are run. If no priority is specified, queries associated with the queue have a priority of `MEDIUM`.

Notes

Use the `gp_toolkit.gp_resqueue_status` system view to see the limit settings and current status of a resource queue:

```
SELECT * from gp_toolkit.gp_resqueue_status WHERE
  rsqname='queue_name';
```

There is also another system view named `pg_stat_resqueue` which shows statistical metrics for a resource queue over time. To use this view, however, you must enable the `stats_queue_level` server configuration parameter. See "Managing Workload and Resources" in the *WarehousePG Administrator Guide* for more information about using resource queues.

`CREATE RESOURCE QUEUE` cannot be run within a transaction.

Also, an SQL statement that is run during the execution time of an `EXPLAIN ANALYZE` command is excluded from resource queues.

Examples

Create a resource queue with an active query limit of 20:

```
CREATE RESOURCE QUEUE myqueue WITH (ACTIVE_STATEMENTS=20);
```

Create a resource queue with an active query limit of 20 and a total memory limit of 2000MB (each query will be allocated 100MB of segment host memory at execution time):

```
CREATE RESOURCE QUEUE myqueue WITH (ACTIVE_STATEMENTS=20,
  MEMORY_LIMIT='2000MB');
```

Create a resource queue with a query cost limit of 3000.0:

```
CREATE RESOURCE QUEUE myqueue WITH (MAX_COST=3000.0);
```

Create a resource queue with a query cost limit of 310 (or 30000000000.0) and do not allow overcommit. Allow small queries with a cost under 500 to run immediately:

```
CREATE RESOURCE QUEUE myqueue WITH (MAX_COST=3e+10,
  COST_OVERCOMMIT=FALSE, MIN_COST=500.0);
```

Create a resource queue with both an active query limit and a query cost limit:

```
CREATE RESOURCE QUEUE myqueue WITH (ACTIVE_STATEMENTS=30,
  MAX_COST=5000.00);
```

Create a resource queue with an active query limit of 5 and a maximum priority setting:

```
CREATE RESOURCE QUEUE myqueue WITH (ACTIVE_STATEMENTS=5,
  PRIORITY=MAX);
```

Compatibility

`CREATE RESOURCE QUEUE` is a WarehousePG extension. There is no provision for resource queues or resource management in the SQL standard.

See Also

ALTER ROLE, CREATE ROLE, ALTER RESOURCE QUEUE, DROP RESOURCE QUEUE

Parent topic: SQL Commands

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7.1.74 CREATE ROLE

Defines a new database role (user or group).

Synopsis

```
CREATE ROLE <name> [[WITH] <option> [ ... ]]
```

where option can be:

```
      SUPERUSER | NOSUPERUSER
    | CREATEDB | NOCREATEDB
    | CREATEROLE | NOCREATEROLE
    | CREATEEXTTABLE | NOCREATEEXTTABLE
      [ ( <attribute>='<value>'[, ...] ) ]
           where <attributes> and <value> are:
           type='readable'|'writable'
           protocol='gpfdist'|'http'
    | INHERIT | NOINHERIT
    | LOGIN | NOLOGIN
    | REPLICATION | NOREPLICATION
    | BYPASSRLS | NOBYPASSRLS
    | CONNECTION LIMIT <connlimit>
    | [ ENCRYPTED ] PASSWORD '<password>' | PASSWORD NULL
    | VALID UNTIL '<timestamp>'
    | IN ROLE <role_name> [, ...]
    | IN GROUP <role_name> [, ...]
    | ROLE <role_name> [, ...]
    | ADMIN <role_name> [, ...]
    | USER <role_name> [, ...]
    | SYSID <uid> [, ...]
    | RESOURCE QUEUE <queue_name>
    | RESOURCE GROUP <group_name>
    | [ DENY <deny_point> ]
    | [ DENY BETWEEN <deny_point> AND <deny_point>]
```

Description

`CREATE ROLE` adds a new role to a WarehousePG cluster. A role is an entity that can own database objects and have database privileges. A role can be considered a user, a group, or both depending on how it is used. You must have `CREATEROLE` privilege or be a database superuser to use this command.

Note that roles are defined at the system-level and are valid for all databases in your WarehousePG cluster.

Parameters

name

The name of the new role.

SUPERUSER

NOSUPERUSER

These clauses determine whether the new role is a "superuser". If `SUPERUSER` is specified, the role being defined will be a superuser, who can override all access restrictions within the database. Superuser status is dangerous and should be used only when really needed. You must yourself be a superuser to create a new superuser. `NOSUPERUSER` is the default.

CREATEDB

NOCREATEDB

These clauses define a role's ability to create databases. If `CREATEDB` is specified, the role being defined will be allowed to create new databases. Specifying `NOCREATEDB` (the default) will deny a role the ability to create databases.

CREATEROLE

NOCREATEROLE

These clauses determine whether a role will be permitted to create new roles (that is, execute `CREATE ROLE`). If `CREATEROLE` is specified, the role being defined will be allowed to create new roles, alter other roles, and drop other roles. `NOCREATEROLE` (the default) will deny a role the ability to create roles or modify roles other than their own.

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CREATEEXTTABLE

NOCREATEEXTTABLE

If `CREATEEXTTABLE` is specified, the role being defined is allowed to create external tables. The default `type` is `readable` and the default `protocol` is `gpfdist`, if not specified. Valid types are `gpfdist`, `gpfdists`, `http`, and `https`. `NOCREATEEXTTABLE` (the default type) denies the role the ability to create external tables. Note that external tables that use the `file` or `execute` protocols can only be created by superusers.

Use the `GRANT...ON PROTOCOL` command to allow users to create and use external tables with a custom protocol type, including the `s3` and `pxf` protocols included with WarehousePG.

INHERIT

NOINHERIT

These clauses determine whether a role "inherits" the privileges of roles it is a member of. If specified, `INHERIT` (the default) allows the role to use whatever database privileges have been granted to all roles it is directly or indirectly a member of. With `NOINHERIT`, membership in another role only grants the ability to `SET ROLE` to that other role; the privileges of the other role are only available after having done so.

LOGIN

NOLOGIN

These clauses determine whether a role is allowed to log in; that is, whether the role can be given as the initial session authorization name during client connection. If specified, `LOGIN` allows a role to log in to a database. A role having the `LOGIN` attribute can be thought of as a user. Roles with `NOLOGIN` are useful for managing database privileges, but are not users in the usual sense of the word. If not specified, `NOLOGIN` is the default, except when `CREATE ROLE` is invoked through its alternative spelling CREATE USER.

REPLICATION

NOREPLICATION

These clauses determine whether a role is a replication role. A role must have this attribute (or be a superuser) in order to be able to connect to the server in replication mode (physical or logical replication) and in order to be able to create or drop replication slots. A role having the `REPLICATION` attribute is a very highly privileged role, and should only be used on roles actually used for replication. If not specified, `NOREPLICATION` is the default. You must be a superuser to create a new role having the `REPLICATION` attribute.

BYPASSRLS

NOBYPASSRLS

These clauses determine whether a role bypasses every row-level security (RLS) policy. `NOBYPASSRLS` is the default. You must be a superuser to create a new role having the `BYPASSRLS` attribute.

Note that `pg_dump` will set row_security to `OFF` by default, to ensure all contents of a table are dumped out. If the user running `pg_dump` does not have appropriate permissions, an error will be returned. However, superusers and the owner of the table being dumped always bypass RLS.

CONNECTION LIMIT connlimit

If role can log in, this specifies how many concurrent connections the role can make. The default of `-1` means there is no limit. Note that only normal connections are counted towards this limit. Neither prepared transactions nor background worker connections are counted towards this limit.

[ENCRYPTED] PASSWORD 'password'

PASSWORD NULL

Sets the role's password. (A password is only of use for roles having the `LOGIN` attribute, but you can nonetheless define one for roles without it.) If you do not plan to use password authentication you can omit this option. If no password is specified, the password will be set to null and password authentication will always fail for that user. A null password can optionally be written explicitly as `PASSWORD NULL`.

```
<div class="note"><b>Note:</b>  Specifying an empty string will also set the password to null, but that was not the case before WarehousePG version 7. In earlier versions, an empty string could be used, or not, depending on the authentication method and the exact version, and `libpq` would refuse to use it in any case. To avoid the ambiguity, specifying an empty string should be avoided.</div>
```

The password is always stored encrypted in the system catalogs. The `ENCRYPTED` keyword has no effect, but is accepted for backwards compatibility. The method of encryption is determined by the configuration parameter `password_encryption`. If the presented password string is already in MD5-encrypted or SCRAM-encrypted format, then it is stored as-is regardless of `password_encryption` (since the system cannot decrypt the specified encrypted password string, to encrypt it in a different format). This allows reloading of encrypted passwords during dump/restore.

VALID UNTIL 'timestamp'

The VALID UNTIL clause sets a date and time after which the role's password is no longer valid. If this clause is omitted the password will never expire.

IN ROLE role_name

Adds the new role as a member of the named roles. (Note that there is no option to add the new role as an administrator; use a separate `GRANT` command to do that.)

IN GROUP role_name

`IN GROUP` is an obsolete spelling of `IN ROLE`.

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ROLE role_name

Adds the named roles as members of this role. (This in effect makes the new role a "group".)

ADMIN rolename

The `ADMIN` clause is like `ROLE`, but the named roles are added to the new role `WITH ADMIN OPTION`, giving them the right to grant membership in this role to others.

USER role_name

The `USER` clause is an obsolete spelling of the `ROLE` clause.

SYSID uid

The `SYSID` clause is ignored, but is accepted for backwards compatibility.

RESOURCE GROUP group_name

The name of the resource group to assign to the new role. The role will be subject to the concurrent transaction, memory, and CPU limits configured for the resource group. You can assign a single resource group to one or more roles.

If you do not specify a resource group for a new role, the role is automatically assigned the default resource group for the role's capability, `admin_group` for `SUPERUSER` roles, `default_group` for non-admin roles.

You can assign the `admin_group` resource group to any role having the `SUPERUSER` attribute.

You can assign the `default_group` resource group to any role.

You cannot assign a resource group that you create for an external component to a role.

RESOURCE QUEUE queue_name

The name of the resource queue to which the new user-level role is to be assigned. Only roles with `LOGIN` privilege can be assigned to a resource queue. The special keyword `NONE` means that the role is assigned to the default resource queue. A role can only belong to one resource queue.

Roles with the `SUPERUSER` attribute are exempt from resource queue limits. For a superuser role, queries always run immediately regardless of limits imposed by an assigned resource queue.

DENY deny_point

DENY BETWEEN deny_point AND deny_point

The `DENY` and `DENY BETWEEN` keywords set time-based constraints that are enforced at login. `DENY` sets a day or a day and time to deny access. `DENY BETWEEN` sets an interval during which access is denied. Both use the parameter deny_point that has the following format:

```
DAY day [ TIME 'time' ]
```

The two parts of the `deny_point` parameter use the following formats:

For `day`:

```
{'Sunday' | 'Monday' | 'Tuesday' |'Wednesday' | 'Thursday' | 'Friday' |
'Saturday' | 0-6 }
```

For `time`:

```
{ 00-23 : 00-59 | 01-12 : 00-59 { AM | PM }}
```

The `DENY BETWEEN` clause uses two deny_point parameters:

```
DENY BETWEEN <deny_point> AND <deny_point>
```

Notes

Use ALTER ROLE to change the attributes of a role, and DROP ROLE to remove a role. All the attributes specified by `CREATE ROLE` can be modified by later `ALTER ROLE` commands.

The preferred way to add and remove role members of roles is to use GRANT and REVOKE.

The `VALID UNTIL` clause defines an expiration time for a password only, not for the role *per se*. The expiration time is not enforced when logging in using a non-password-based authentication method.

The `INHERIT` attribute governs inheritance of grantable privileges (access privileges for database objects and role memberships). It does not apply to the special role attributes set by `CREATE ROLE` and `ALTER ROLE`. For example, being a member of a role with `CREATEDB` privilege does not immediately grant the ability to create databases, even if `INHERIT` is set; it would be necessary to become that role via SET ROLE before creating a database.

The `INHERIT` attribute is the default for reasons of backwards compatibility. In prior releases of WarehousePG, users always had access to all privileges of groups they were members of. However, `NOINHERIT` provides a closer match to the semantics specified in the SQL standard.

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Be careful with the `CREATEROLE` privilege. There is no concept of inheritance for the privileges of a `CREATEROLE`-role. That means that even if a role does not have a certain privilege but is allowed to create other roles, it can easily create another role with different privileges than its own (except for creating roles with superuser privileges). For example, if a role has the `CREATEROLE` privilege but not the `CREATEDB` privilege, it can create a new role with the `CREATEDB` privilege. Therefore, regard roles that have the `CREATEROLE` privilege as almost-superuser-roles.

WarehousePG includes a program createuser that has the same functionality as `CREATE ROLE` (in fact, it calls this command) but can be run from the command shell.

The `CONNECTION LIMIT` option is only enforced approximately; if two new sessions start at about the same time when just one connection "slot" remains for the role, it is possible that both will fail. Also, the limit is never enforced for superusers.

You must exercise caution when specifying an unencrypted password with this command. The password will be transmitted to the server in clear-text, and it might also be logged in the client's command history or the server log. The client program createuser, however, transmits the password encrypted. Also, psql contains a command `\password` that can be used to safely change the password later.

Examples

Create a role that can log in, but don't give it a password:

```
CREATE ROLE jonathan LOGIN;
```

Create a role with a password:

```
CREATE USER davide WITH PASSWORD 'jw8s0F4';
```

(`CREATE USER` is the same as `CREATE ROLE` except that it implies `LOGIN`.)

Create a role with a password that is valid until the end of 2022:

```
CREATE USER joelle WITH LOGIN PASSWORD 'jw8s0F4' VALID UNTIL '2023-01-01';
```

Create a role that can create databases and manage other roles:

```
CREATE ROLE admin WITH CREATEDB CREATEROLE;
```

Create a role that does not allow login access on Sundays:

```
CREATE ROLE user3 DENY DAY 'Sunday';
```

Create a role that can create readable and writable external tables of type 'gpfdist':

```
CREATE ROLE jan WITH CREATEEXTTABLE(type='readable', protocol='gpfdist')
   CREATEEXTTABLE(type='writable', protocol='gpfdist');
```

Create a role, assigning a resource group:

```
CREATE ROLE bill RESOURCE GROUP rg_light;
```

Create a role that belongs to a resource queue:

```
CREATE ROLE jonathan LOGIN RESOURCE QUEUE poweruser;
```

Compatibility

`CREATE ROLE` is in the SQL standard, but the standard only requires the syntax:

```
CREATE ROLE <name> [WITH ADMIN <rolename>]
```

Allowing multiple initial administrators, and all the other options of `CREATE ROLE`, are WarehousePG extensions.

The SQL standard defines the concepts of users and roles, but it regards them as distinct concepts and leaves all commands defining users to be specified by the database implementation. In WarehousePG users and roles are unified into a single type of object. Roles therefore have many more optional attributes than they do in the standard.

The behavior specified by the SQL standard is most closely approximated by giving users the `NOINHERIT` attribute, while roles are given the `INHERIT` attribute.

See Also

SET ROLE, ALTER ROLE, DROP ROLE, GRANT, REVOKE, CREATE RESOURCE QUEUE CREATE RESOURCE GROUP, createuser

Parent topic: SQL Commands

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7.1.75 CREATE RULE

Defines a new rewrite rule.

Synopsis

```
CREATE [OR REPLACE] RULE <name> AS ON <event>
  TO <table_name> [WHERE <condition>]
  DO [ALSO | INSTEAD] { NOTHING | <command> | (<command>; <command>
  ...) }

where <event> can be one of:

  SELECT | INSERT | UPDATE | DELETE
```

Description

`CREATE RULE` defines a new rule applying to a specified table or view. `CREATE OR REPLACE RULE` will either create a new rule, or replace an existing rule of the same name for the same table.

The WarehousePG rule system allows one to define an alternate action to be performed on insertions, updates, or deletions in database tables. A rule causes additional or alternate commands to be run when a given command on a given table is run. An `INSTEAD` rule can replace a given command by another, or cause a command to not be run at all. Rules can be used to implement SQL views as well. It is important to realize that a rule is really a command transformation mechanism, or command macro. The transformation happens before the execution of the command starts. It does not operate independently for each physical row as does a trigger.

`ON SELECT` rules must be unconditional `INSTEAD` rules and must have actions that consist of a single `SELECT` command. Thus, an `ON SELECT` rule effectively turns the table into a view, whose visible contents are the rows returned by the rule's `SELECT` command rather than whatever had been stored in the table (if anything). It is considered better style to write a `CREATE VIEW` command than to create a real table and define an `ON SELECT` rule for it.

You can create the illusion of an updatable view by defining `ON INSERT`, `ON UPDATE`, and `ON DELETE` rules (or any subset of those that is sufficient for your purposes) to replace update actions on the view with appropriate updates on other tables. If you want to support `INSERT RETURNING` and so on, be sure to put a suitable `RETURNING` clause into each of these rules.

There is a catch if you try to use conditional rules for complex view updates: there *must* be an unconditional `INSTEAD` rule for each action you wish to allow on the view. If the rule is conditional, or is not `INSTEAD`, then the system will still reject attempts to perform the update action, because it thinks it might end up trying to perform the action on the dummy table of the view in some cases. If you want to handle all of the useful cases in conditional rules, add an unconditional `DO INSTEAD NOTHING` rule to ensure that the system understands it will never be called on to update the dummy table. Then make the conditional rules non `INSTEAD`; in the cases where they are applied, they add to the default `INSTEAD NOTHING` action. (This method does not currently work to support `RETURNING` queries, however.)

> **Note** A view that is simple enough to be automatically updatable (see CREATE VIEW) does not require a user-created rule in order to be updatable. While you can create an explicit rule anyway, the automatic update transformation will generally outperform an explicit rule.

Parameters

name The name of a rule to create. This must be distinct from the name of any other rule for the same table. Multiple rules on the same table and same event type are applied in alphabetical name order.

event The event is one of `SELECT`, `INSERT`, `UPDATE`, or `DELETE`. Note that an `INSERT` containing an `ON CONFLICT` clause cannot be used on tables that have either `INSERT` or `UPDATE` rules. Consider using an updatable view instead.

table_name The name (optionally schema-qualified) of the table or view the rule applies to.

condition Any SQL conditional expression (returning `boolean`). The condition expression can not refer to any tables except `NEW` and `OLD`, and can not contain aggregate functions.

INSTEAD `INSTEAD` indicates that the commands should be run *instead of* the original command.

ALSO `ALSO` indicates that the commands should be run *in addition* to the original command. If neither `ALSO` nor `INSTEAD` is specified, `ALSO` is the default.

command The command or commands that make up the rule action. Valid commands are `SELECT`, `INSERT`, `UPDATE`, `DELETE`, or `NOTIFY`.

Within condition and command, the special table names `NEW` and `OLD` can be used to refer to values in the referenced table. `NEW` is valid in `ON INSERT` and `ON UPDATE` rules to refer to the new row being inserted or updated. `OLD` is valid in `ON UPDATE` and `ON DELETE` rules to refer to the existing row being updated or deleted.

Notes

You must be the owner of a table to create or change rules for it.

In a rule for `INSERT`, `UPDATE`, or `DELETE` on a view, you can add a `RETURNING` clause that emits the view's columns. This clause will be used to compute the outputs if the rule is triggered by an `INSERT RETURNING`, `UPDATE RETURNING`, or `DELETE RETURNING` command respectively. When the rule is triggered by a command without `RETURNING`, the rule's `RETURNING` clause will be ignored. The current implementation allows only unconditional `INSTEAD` rules to contain `RETURNING`; furthermore there can be at most one `RETURNING` clause among all the rules for the same event. (This ensures that there is only one candidate `RETURNING` clause to be used to compute the results.) `RETURNING` queries on the view will be rejected if there is no `RETURNING` clause in any available rule.

It is very important to take care to avoid circular rules. For example, though each of the following two rule definitions are accepted by WarehousePG, the `SELECT` command would cause WarehousePG to report an error because of recursive expansion of a rule:

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```
CREATE RULE "_RETURN" AS
    ON SELECT TO t1
    DO INSTEAD
        SELECT * FROM t2;

CREATE RULE "_RETURN" AS
    ON SELECT TO t2
    DO INSTEAD
        SELECT * FROM t1;

SELECT * FROM t1;
```

If a rule action contains a `NOTIFY` command, the `NOTIFY` command will be executed unconditionally, that is, the `NOTIFY` will be issued even if there are not any rows that the rule should apply to. For example, in:

```
CREATE RULE notify_me AS ON UPDATE TO mytable DO ALSO NOTIFY mytable;

UPDATE mytable SET name = 'foo' WHERE id = 42;
```

one `NOTIFY` event will be sent during the `UPDATE`, whether or not there are any rows that match the condition id = 42.

Compatibility

`CREATE RULE` is a WarehousePG extension, as is the entire query rewrite system.

See Also

ALTER RULE, DROP RULE

Parent topic: SQL Commands

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7.1.76 CREATE SCHEMA

Defines a new schema.

Synopsis

```
CREATE SCHEMA <schema_name> [AUTHORIZATION <role_specification>]
   [<schema_element> [ ... ]]

CREATE SCHEMA AUTHORIZATION <role_specification> [<schema_element> [ ... ]]

CREATE SCHEMA IF NOT EXISTS <schema_name> [ AUTHORIZATION <role_specification> ]

CREATE SCHEMA IF NOT EXISTS AUTHORIZATION <role_specification>

where <role_specification> can be:

    <user_name>
  | CURRENT_USER
  | SESSION_USER
```

Description

`CREATE SCHEMA` enters a new schema into the current database. The schema name must be distinct from the name of any existing schema in the current database.

A schema is essentially a namespace: it contains named objects (tables, data types, functions, and operators) whose names may duplicate those of other objects existing in other schemas. Named objects are accessed either by qualifying their names with the schema name as a prefix, or by setting a search path that includes the desired schema(s). A `CREATE` command specifying an unqualified object name creates the object in the current schema (the one at the front of the search path, which can be determined with the function `current_schema()`).

Optionally, `CREATE SCHEMA` can include subcommands to create objects within the new schema. The subcommands are treated essentially the same as separate commands issued after creating the schema, except that if the `AUTHORIZATION` clause is used, all the created objects will be owned by that role.

Parameters

schema*name The name of a schema to be created. If this is omitted, the user_name is used as the schema name. The name cannot begin with `pg`*, as such names are reserved for system catalog schemas.

user_name The role name of the user who will own the new schema. If omitted, defaults to the user running the command. To create a schema owned by another role, you must be a direct or indirect member of that role, or be a superuser.

schema_element An SQL statement defining an object to be created within the schema. Currently, only `CREATE TABLE`, `CREATE VIEW`, `CREATE INDEX`, `CREATE SEQUENCE`, `CREATE TRIGGER`, and `GRANT` are accepted as clauses within `CREATE SCHEMA`. Other kinds of objects may be created in separate commands after the schema is created.

```
> **Note** WarehousePG does not support triggers.
```

`IF NOT EXISTS` Do nothing (except issuing a notice) if a schema with the same name already exists. schema_element subcommands cannot be included when this option is used.

Notes

To create a schema, the invoking user must have the `CREATE` privilege for the current database or be a superuser.

Examples

Create a schema:

```
CREATE SCHEMA myschema;
```

Create a schema for role `joe`; the schema will also be named `joe`:

```
CREATE SCHEMA AUTHORIZATION joe;
```

Create a schema named `test` that will be owned by user `joe`, unless there already is a schema named `test`. (It does not matter whether `joe` owns the pre-existing schema.)

```
CREATE SCHEMA IF NOT EXISTS test AUTHORIZATION joe;
```

Create a schema and create a table and view within it:

```
CREATE SCHEMA hollywood
    CREATE TABLE films (title text, release date, awards text[])
    CREATE VIEW winners AS
        SELECT title, release FROM films WHERE awards IS NOT NULL;
```

Notice that the individual subcommands do not end with semicolons.

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The following is an equivalent way of accomplishing the same result:

```
CREATE SCHEMA hollywood;
CREATE TABLE hollywood.films (title text, release date, awards text[]);
CREATE VIEW hollywood.winners AS
    SELECT title, release FROM hollywood.films WHERE awards IS NOT NULL;
```

Compatibility

The SQL standard allows a `DEFAULT CHARACTER SET` clause in `CREATE SCHEMA`, as well as more subcommand types than are presently accepted by WarehousePG.

The SQL standard specifies that the subcommands in `CREATE SCHEMA` may appear in any order. The present WarehousePG implementation does not handle all cases of forward references in subcommands; it may sometimes be necessary to reorder the subcommands in order to avoid forward references.

According to the SQL standard, the owner of a schema always owns all objects within it. WarehousePG allows schemas to contain objects owned by users other than the schema owner. This can happen only if the schema owner grants the `CREATE` privilege on the schema to someone else, or a superuser chooses to create objects in it.

The `IF NOT EXISTS` option is a WarehousePG extension.

See Also

ALTER SCHEMA, DROP SCHEMA

Parent topic: SQL Commands

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7.1.77 CREATE SEQUENCE

Defines a new sequence generator.

Synopsis

```
CREATE [TEMPORARY | TEMP] SEQUENCE [IF NOT EXISTS] <name>
       [ AS data_type ]
       [INCREMENT [BY] <increment>]
       [MINVALUE <minvalue> | NO MINVALUE]
       [MAXVALUE <maxvalue> | NO MAXVALUE]
       [START [ WITH ] <start>]
       [CACHE <cache>]
       [[NO] CYCLE]
       [OWNED BY { <table_name>.<column_name> | NONE }]
```

Description

`CREATE SEQUENCE` creates a new sequence number generator. This involves creating and initializing a new special single-row table with the same name. The generator will be owned by the user issuing the command.

If a schema name is given, then the sequence is created in the specified schema. Otherwise it is created in the current schema. Temporary sequences exist in a special schema, so you may not provide a schema name when creating a temporary sequence. The sequence name must be distinct from the name of any other sequence, table, index, view, or foreign table in the same schema.

After a sequence is created, you use the `nextval()` function to operate on the sequence. For example, to insert a row into a table that gets the next value of a sequence:

```
INSERT INTO distributors VALUES (nextval('myserial'), 'acme');
```

You can also use the function `setval()` to operate on a sequence, but only for queries that do not operate on distributed data. For example, the following query is allowed because it resets the sequence counter value for the sequence generator process on the coordinator:

```
SELECT setval('myserial', 201);
```

But the following query will be rejected in WarehousePG because it operates on distributed data:

```
INSERT INTO product VALUES (setval('myserial', 201), 'gizmo');
```

In a regular (non-distributed) database, functions that operate on the sequence go to the local sequence table to get values as they are needed. In WarehousePG, however, keep in mind that each segment is its own distinct database process. Therefore the segments need a single point of truth to go for sequence values so that all segments get incremented correctly and the sequence moves forward in the right order. A sequence server process runs on the coordinator and is the point-of-truth for a sequence in a WarehousePG distributed database. Segments get sequence values at runtime from the coordinator.

Because of this distributed sequence design, there are some limitations on the functions that operate on a sequence in WarehousePG:

- `lastval()` and `currval()` functions are not supported.
- `setval()` can only be used to set the value of the sequence generator on the coordinator, it cannot be used in subqueries to update records on distributed table data.
- `nextval()` sometimes grabs a block of values from the coordinator for a segment to use, depending on the query. So values may sometimes be skipped in the sequence if all of the block turns out not to be needed at the segment level. Note that a regular PostgreSQL database does this too, so this is not something unique to WarehousePG.

> **Note** The default sequence cache size in WarehousePG is `20`.

Although you cannot update a sequence directly, you can use a query like:

```
SELECT * FROM <sequence_name>;
```

to examine the parameters and current state of a sequence. In particular, the last_value field of the sequence shows the last value allocated by any session. (Note that this value might be obsolete by the time it's printed, if other sessions are actively doing `nextval()` calls.)

Parameters

TEMPORARY | TEMP If specified, the sequence object is created only for this session, and is automatically dropped on session exit. Existing permanent sequences with the same name are not visible (in this session) while the temporary sequence exists, unless they are referenced with schema-qualified names.

IF NOT EXISTS Do not throw an error if a relation with the same name already exists. WarehousePG issues a notice in this case. Note that there is no guarantee that the existing relation is anything like the sequence that would have been created - it might not even be a sequence.

name The name (optionally schema-qualified) of the sequence to be created.

data_type The optional clause `AS data_type` specifies the data type of the sequence. Valid types are `smallint`, `integer`, and `bigint`. `bigint` is the default. The data type determines the default minimum and maximum values of the sequence.

increment Specifies which value is added to the current sequence value to create a new value. A positive value will make an ascending sequence, a negative one a descending sequence. The default value is `1`.

minvalue NO MINVALUE Determines the minimum value a sequence can generate. If this clause is not supplied or `NO MINVALUE` is specified, then the default values will be used. The default for an ascending sequence is the maximum value of the data type. The default for a descending sequence is `-1`.

maxvalue NO MAXVALUE Determines the maximum value for the sequence. If this clause is not supplied or `NO MAXVALUE` is specified, then default values will be used. The defaults are 263-1 and -1 for ascending and descending sequences, respectively.

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start Allows the sequence to begin anywhere. The default starting value is `minvalue` for ascending sequences and `maxvalue` for descending ones.

cache Specifies how many sequence numbers are to be preallocated and stored in memory for faster access. The default value is 20. The minimum value is 1 (no cache).

> **Note** When operating with a cache of sequence numbers (`cache > 1`), WarehousePG may discard some cached sequence values. If you require consecutive values, you must explicitly set `CACHE 1` when you create or alter the sequence.

CYCLE NO CYCLE Allows the sequence to wrap around when the `maxvalue` (for ascending) or `minvalue` (for descending) has been reached. If the limit is reached, the next number generated will be the `minvalue` (for ascending) or `maxvalue` (for descending). If `NO CYCLE` is specified, any calls to `nextval()` after the sequence has reached its maximum value will return an error. If neither `CYCLE` or `NO CYCLE` are specified, `NO CYCLE` is the default.

OWNED BY table_name.colume_name OWNED BY NONE Causes the sequence to be associated with a specific table column, such that if that column (or its whole table) is dropped, the sequence will be automatically dropped as well. The specified table must have the same owner and be in the same schema as the sequence. `OWNED BY NONE` , the default, specifies that there is no such association.

Notes

Use `DROP SEQUENCE` to remove a sequence.

Sequences are based on bigint arithmetic, so the range cannot exceed the range of an eight-byte integer (-9223372036854775808 to 9223372036854775807).

Because `nextval()` and `setval()` calls are never rolled back, sequence objects cannot be used if "gapless" assignment of sequence numbers is needed. It is possible to build gapless assignment by using exclusive locking of a table containing a counter; but this solution is much more expensive than sequence objects, especially if many transactions need sequence numbers concurrently.

Although multiple sessions are guaranteed to allocate distinct sequence values, the values may be generated out of sequence when all the sessions are considered. For example, with a `cache` setting of `10` , session A might reserve values 1..10 and return `nextval=1` , then session B might reserve values 11..20 and return `nextval=11` before session A has generated nextval=2. Thus, with a `cache` setting of one it is safe to assume that `nextval()` values are generated sequentially; with a `cache` setting greater than one you should only assume that the `nextval()` values are all distinct, not that they are generated purely sequentially.

Another consideration is that a `setval()` executed on such a sequence will not be noticed by other sessions until they have used up any preallocated values they have cached.

Examples

Create an ascending sequence named `myseq` , starting at 101:

```
CREATE SEQUENCE myseq START 101;
```

Insert a row into a table that gets the next value of the sequence named `myseq` :

```
INSERT INTO distributors VALUES (nextval('myseq'), 'acme');
```

Reset the sequence counter value on the WarehousePG coordinator:

```
SELECT setval('myseq', 201);
```

Illegal use of `setval()` in WarehousePG (setting sequence values on distributed data):

```
INSERT INTO product VALUES (setval('myseq', 201), 'gizmo');
```

Compatibility

`CREATE SEQUENCE` conforms to the SQL standard, with the following exceptions:

- You obtain the next value using the `nextval()` function instead of the `NEXT VALUE FOR` expression specified in the SQL standard.
- The `OWNED BY` clause is a WarehousePG extension.

See Also

ALTER SEQUENCE, DROP SEQUENCE

Parent topic: SQL Commands

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7.1.78 CREATE SERVER

Defines a new foreign server.

Synopsis

```
CREATE SERVER [ IF NOT EXISTS ] <server_name> [ TYPE '<server_type>' ] [ VERSION '<server_version>' ]
    FOREIGN DATA WRAPPER <fdw_name>
    [ OPTIONS ( [ mpp_execute { 'coordinator' | 'any' | 'all segments' } [, ] ]
                [ num_segments '<num>' [, ] ]
                [ <option> '<value>' [, ... ]] ) ]
```

Description

`CREATE SERVER` defines a new foreign server. The user who defines the server becomes its owner.

A foreign server typically encapsulates connection information that a foreign-data wrapper uses to access an external data source. Additional user-specific connection information may be specified by means of user mappings.

Creating a server requires the `USAGE` privilege on the foreign-data wrapper specified.

Parameters

IF NOT EXISTS

Do not throw an error if a server with the same name already exists. WarehousePG issues a notice in this case. Note that there is no guarantee that the existing server is anything like the one that would have been created.

server_name The name of the foreign server to create. The server name must be unique within the database.

server_type Optional server type, potentially useful to foreign-data wrappers.

server_version Optional server version, potentially useful to foreign-data wrappers.

fdw_name Name of the foreign-data wrapper that manages the server.

OPTIONS (option 'value' [, ...]) The options for the new foreign server. The options typically define the connection details of the server, but the actual names and values are dependent upon the server's foreign-data wrapper.

mpp_execute { 'coordinator' | 'any' | 'all segments' } A WarehousePG-specific option that identifies the host from which the foreign-data wrapper reads or writes data:

```
-   `coordinator` \(the default\)—Read or write data from the coordinator host.
-   `any`—Read data from either the coordinator host or any one segment, depending on which path costs less.
-   `all segments`—Read or write data from all segments. To support this option value, the foreign-data wrapper should have a policy that matches the segments to
data.

> **Note** WarehousePG supports parallel writes to foreign tables only when you set `mpp_execute 'all segments'`.

Support for the foreign server `mpp_execute` option, and the specific modes, is foreign-data wrapper-specific.

The `mpp_execute` option can be specified in multiple commands: `CREATE FOREIGN TABLE`, `CREATE SERVER`, and `CREATE FOREIGN DATA WRAPPER`. The foreign table
setting takes precedence over the foreign server setting, followed by the foreign-data wrapper setting.
```

num_segments 'num' When `mpp_execute` is set to `'all segments'`, the WarehousePG-specific `num_segments` option identifies the number of query executors that WarehousePG spawns on the source WarehousePG cluster. If you do not provide a value, num defaults to the number of segments in the source cluster.

```
Support for the foreign server `num_segments` option is foreign-data wrapper-specific.
```

Notes

When using the dblink module (see dblink), you can use the foreign server name as an argument of the `dblink_connect()` function to provide the connection parameters. You must have the `USAGE` privilege on the foreign server to use it in this manner.

Examples

Create a foreign server named `myserver` that uses a foreign-data wrapper named `gpfdw1` and includes connection options:

```
CREATE SERVER myserver FOREIGN DATA WRAPPER gpfdw1
    OPTIONS (host 'foo', dbname 'foodb', port '5432');
```

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Compatibility

`CREATE SERVER` conforms to ISO/IEC 9075-9 (SQL/MED).

See Also

ALTER SERVER, DROP SERVER, CREATE FOREIGN DATA WRAPPER, CREATE FOREIGN TABLE, CREATE USER MAPPING

Parent topic: SQL Commands

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7.1.79 CREATE STATISTICS

Defines extended statistics.

Synopsis

```
CREATE STATISTICS [ IF NOT EXISTS ] <statistics_name>
    [ ( <statistics_kind> [, ... ] ) ]
    ON <column_name>, <column_name> [, ...]
    FROM <table_name>
```

Description

`CREATE STATISTICS` creates a new extended statistics object tracking data about the specified table, foreign table, or materialized view. The statistics object is created in the current database and will be owned by the user issuing the command.

If a schema name is given (for example, `CREATE STATISTICS myschema.mystat ...`) then the statistics object is created in the specified schema. Otherwise it is created in the current schema. The name of the statistics object must be distinct from the name of any other statistics object in the same schema.

Parameters

IF NOT EXISTS

Do not throw an error if a statistics object with the same name already exists. WarehousePG issues a notice in this case. Note that only the name of the statistics object is considered here, not the details of its definition.

statistics_name The name (optionally schema-qualified) of the statistics object to create.

statistics_kind A statistics kind to be computed in this statistics object. Currently supported kinds are `ndistinct`, which enables n-distinct statistics, `dependencies`, which enables functional dependency statistics, and `mcv` which enables most-common values lists. If this clause is omitted, all supported statistics kinds are included in the statistics object.

column_name The name of a table column to be covered by the computed statistics. You must specify at least two column names; the order of the column names is insignificant.

table_name The name (optionally schema-qualified) of the table containing the column(s) on which the statistics are computed; seeANALYZE for an explanation of inheritance and partition handling.

Notes

You must be the owner of a table to create a statistics object that reads it. Once created, however, the ownership of the statistics object is independent of the underlying table(s).

Examples

Create table `t1` with two functionally-dependent columns, i.e., knowledge of a value in the first column is sufficient for determining the value in the other column. Then build functional dependency statistics on those columns:

```
CREATE TABLE t1 (
    a   int,
    b   int
);

INSERT INTO t1 SELECT i/100, i/500
                FROM generate_series(1,1000000) s(i);

ANALYZE t1;

-- the number of matching rows will be drastically underestimated:
EXPLAIN ANALYZE SELECT * FROM t1 WHERE (a = 1) AND (b = 0);

CREATE STATISTICS s1 (dependencies) ON a, b FROM t1;

ANALYZE t1;

-- now the row count estimate is more accurate:
EXPLAIN ANALYZE SELECT * FROM t1 WHERE (a = 1) AND (b = 0);
```

Without functional-dependency statistics, the planner assumes that the two `WHERE` conditions are independent, and would multiply their selectivities together to arrive at a much-too-small row count estimate. With such statistics, the planner recognizes that the `WHERE` conditions are redundant and does not underestimate the row count.

Create table `t2` with two perfectly correlated columns (containing identical data), and a MCV list on those columns:

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```
CREATE TABLE t2 (
    a   int,
    b   int
);

INSERT INTO t2 SELECT mod(i,100), mod(i,100)
                FROM generate_series(1,1000000) s(i);

CREATE STATISTICS s2 (mcv) ON a, b FROM t2;

ANALYZE t2;

-- valid combination (found in MCV)
EXPLAIN ANALYZE SELECT * FROM t2 WHERE (a = 1) AND (b = 1);

-- invalid combination (not found in MCV)
EXPLAIN ANALYZE SELECT * FROM t2 WHERE (a = 1) AND (b = 2);
```

The MCV list gives the planner more detailed information about the specific values that commonly appear in the table, as well as an upper bound on the selectivities of combinations of values that do not appear in the table, allowing it to generate better estimates in both cases.

Compatibility

There is no `CREATE STATISTICS` statement in the SQL standard.

See Also

ALTER STATISTICS, DROP STATISTICS

Parent topic: SQL Commands

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7.1.80 CREATE TABLE

Defines a new table.

Note WarehousePG accepts, but does not enforce, referential integrity syntax (foreign key constraints).

Synopsis

```
CREATE [ [GLOBAL | LOCAL] {TEMPORARY | TEMP} | UNLOGGED ] TABLE [IF NOT EXISTS] <table_name> (
  [ { <column_name> <data_type> [ COLLATE <collation> ] [ ENCODING ( <storage_directive> [, ...] ) ] [<column_constraint> [ ... ] ]
    | <table_constraint>
    | LIKE <source_table> [ <like_option> ... ]
    | COLUMN <column_name> ENCODING ( <storage_directive> [, ...] ) [, ...] }
] )
[ INHERITS ( <parent_table> [, ... ] ) ]
[ PARTITION BY { RANGE | LIST | HASH } ( { <column_name> | ( <expression> ) } [ COLLATE <collation> ] [ <opclass> ] [, ... ] ) ]
[ USING ( <access_method> ) ]
[ WITH ( <storage_parameter> [=<value>] [, ... ] ) ]
[ ON COMMIT { PRESERVE ROWS | DELETE ROWS | DROP } ]
[ TABLESPACE <tablespace_name> ]
[ DISTRIBUTED BY ( <column> [<opclass>] [, ... ] )
    | DISTRIBUTED RANDOMLY
    | DISTRIBUTED REPLICATED
    | DISTRIBUTED COORDINATOR ONLY  ]

CREATE [ [GLOBAL | LOCAL] {TEMPORARY | TEMP} | UNLOGGED ] TABLE [IF NOT EXISTS] <table_name>
  OF <type_name> [ (
  { <column_name> [WITH OPTIONS] [ <column_constraint> [ ... ] ]
    | <table_constraint> }
    [, ... ]
) ]
[ PARTITION BY { RANGE | LIST | HASH } ( { <column_name> | ( <expression> ) } [ COLLATE <collation> ] [ <opclass> ] [, ... ] ) ]
[ USING <access_method> ]
[ WITH ( <storage_parameter> [=<value>] [, ... ] ) ]
[ ON COMMIT { PRESERVE ROWS | DELETE ROWS | DROP } ]
[ TABLESPACE <tablespace_name> ]
[ DISTRIBUTED BY ( <column> [<opclass>] [, ... ] )
    | DISTRIBUTED RANDOMLY
    | DISTRIBUTED REPLICATED
    | DISTRIBUTED COORDINATOR ONLY  ]

CREATE [ [GLOBAL | LOCAL] { TEMPORARY | TEMP } | UNLOGGED ] TABLE [ IF NOT EXISTS ] <table_name>
  PARTITION OF <parent_table> [ (
    | <table_constraint> }
    [, ... ]
) ] { FOR VALUES <partition_bound_spec> | DEFAULT }
[ PARTITION BY { RANGE | LIST | HASH } ( { <column_name> | ( <expression> ) } [ COLLATE <collation> ] [ <opclass> ] [, ... ] ) ]
[ USING <access_method> ]
[ WITH ( <storage_parameter> [=<value>] [, ... ] ) ]
[ ON COMMIT { PRESERVE ROWS | DELETE ROWS | DROP } ]
[ TABLESPACE <tablespace_name> ]

where <column_constraint> is:

  [ CONSTRAINT <constraint_name>]
  { NOT NULL
    | NULL
    | CHECK  ( <expression> ) [ NO INHERIT ]
    | DEFAULT <default_expr>
    | GENERATED ALWAYS AS ( <generation_expr> ) STORED
    | GENERATED { ALWAYS | BY DEFAULT } AS IDENTITY [ ( <sequence_options> ) ]
    | UNIQUE <index_parameters>
    | PRIMARY KEY <index_parameters>
    | REFERENCES <reftable> [ ( refcolumn ) ]
        [ MATCH FULL | MATCH PARTIAL | MATCH SIMPLE ]
        [ ON DELETE <referential_action> ] [ ON UPDATE <referential_action> ] }
  [ DEFERRABLE | NOT DEFERRABLE ] [ INITIALLY DEFERRED | INITIALLY IMMEDIATE ]

and <table_constraint> is:

  [ CONSTRAINT <constraint_name> ]
  { CHECK ( <expression> ) [ NO INHERIT ]
    | UNIQUE ( <column_name> [, ... ] ) <index_parameters>
    | PRIMARY KEY ( <column_name> [, ... ] ) <index_parameters>
    | EXCLUDE [ USING <index_method> ] ( <exclude_element> WITH <operator> [, ... ] )
        <index_parameters> [ WHERE ( <predicate> ) ]
    | FOREIGN KEY ( <column_name> [, ... ] ) REFERENCES <reftable> [ ( <refcolumn> [, ... ] ) ]
        [ MATCH FULL | MATCH PARTIAL | MATCH SIMPLE ]
        [ ON DELETE <referential_action> ] [ ON UPDATE <referential_action> ] }
  [ DEFERRABLE | NOT DEFERRABLE ] [ INITIALLY DEFERRED | INITIALLY IMMEDIATE ]

and <like_option> is:

  { INCLUDING | EXCLUDING }
  { AM | COMMENTS | CONSTRAINTS | DEFAULTS | ENCODING | GENERATED | IDENTITY
       | INDEXES | RELOPT | STATISTICS | STORAGE | ALL }

and <partition_bound_spec> is:
```

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```
  IN ( <partition_bound_expr> [, ...] ) |
  FROM ( { <partition_bound_expr> | MINVALUE | MAXVALUE } [, ...] )
    TO ( { <partition_bound_expr> | MINVALUE | MAXVALUE } [, ...] ) |
  WITH ( MODULUS <numeric_literal>, REMAINDER <numeric_literal> )

and <index_parameters> in UNIQUE, PRIMARY KEY, and EXCLUDE constraints are:

  [ INCLUDE ( <column_name> [, ... ] ) ]
  [ WITH ( <storage_parameter> [=<value>] [, ... ] ) ]
  [ USING INDEX TABLESPACE <tablespace_name> ]

and <exclude_element> in an EXCLUDE constraint is:

  { <column_name> | ( <expression> ) } [ <opclass> ] [ ASC | DESC ] [ NULLS { FIRST | LAST } ]
```

Classic partitioning syntax elements include:

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```
CREATE [ [GLOBAL | LOCAL] {TEMPORARY | TEMP} | UNLOGGED ] TABLE [IF NOT EXISTS] <table_name> (
  [ { <column_name> <data_type> [ COLLATE <collation> ] [ ENCODING ( <storage_directive> [, ...] ) ] [<column_constraint> [ ... ] ]
    | <table_constraint>
    | LIKE <source_table> [ <like_option> ... ]
    | COLUMN <column_name> ENCODING ( <storage_directive> [, ...] ) [, ...] }
] )
[ INHERITS ( <parent_table> [, ... ] ) ]
[ USING ( <access_method> ) ]
[ WITH ( <storage_parameter> [=<value>] [, ... ] ) ]
[ ON COMMIT { PRESERVE ROWS | DELETE ROWS | DROP } ]
[ TABLESPACE <tablespace_name> ]
[ DISTRIBUTED BY ( <column> [<opclass>] [, ... ] )
    | DISTRIBUTED RANDOMLY
    | DISTRIBUTED REPLICATED
    | DISTRIBUTED COORDINATOR ONLY ]

{ --partitioned table using SUBPARTITION TEMPLATE
[ PARTITION BY { RANGE | LIST } (<column>)
  {  [ SUBPARTITION BY { RANGE | LIST } (<column1>)
       SUBPARTITION TEMPLATE ( <template_spec> ) ]
          [ SUBPARTITION BY { RANGE | LIST } (<column2>)
            SUBPARTITION TEMPLATE ( <template_spec> ) ]
              [...]  }
  ( <classic_partition_spec> ) ]
}

|

{ -- partitioned table without SUBPARTITION TEMPLATE
[ PARTITION BY { RANGE | LIST } (<column>)
   [ SUBPARTITION BY { RANGE | LIST } (<column1>) ]
      [ SUBPARTITION BY { RANGE | LIST } (<column2>) ]
         [...]
  ( <classic_partition_spec>
     [ ( <subpartition_spec_column1>
          [ ( <subpartition_spec_column2>
               [...] ) ] ) ],
  [ <classic_partition_spec>
     [ ( <subpartition_spec_column1>
        [ ( <subpartition_spec_column2>
            [...] ) ] ) ], ]
    [...]
  ) ]
}

where <classic_partition_spec> is:

  <partition_element> [, ...]

and <partition_element> is:

   DEFAULT PARTITION <name>
  | [PARTITION <name>] VALUES (<list_value> [,...] )
  | [PARTITION <name>]
     START ([<datatype>] '<start_value>') [INCLUSIVE | EXCLUSIVE]
     [ END ([<datatype>] '<end_value>') [INCLUSIVE | EXCLUSIVE] ]
     [ EVERY ([<datatype>] [<number> | INTERVAL] '<interval_value>') ]
  | [PARTITION <name>]
     END ([<datatype>] '<end_value>') [INCLUSIVE | EXCLUSIVE]
     [ EVERY ([<datatype>] [<number> | INTERVAL] '<interval_value>') ]
[ WITH ( <storage_parameter> = <value> [ , ... ] ) ]
[ <storage_directive> [ , ... ] ]
[ TABLESPACE <tablespace> ]

and <subpartition_spec> or <template_spec> is:

  <subpartition_element> [, ...]

and <subpartition_element> is:

  DEFAULT SUBPARTITION <name>
  | [SUBPARTITION <name>] VALUES (<list_value> [,...] )
  | [SUBPARTITION <name>]
     START ([<datatype>] '<start_value>') [INCLUSIVE | EXCLUSIVE]
     [ END ([<datatype>] '<end_value>') [INCLUSIVE | EXCLUSIVE] ]
     [ EVERY ([<datatype>] [<number> | INTERVAL] '<interval_value>') ]
  | [SUBPARTITION <name>]
     END ([<datatype>] '<end_value>') [INCLUSIVE | EXCLUSIVE]
     [ EVERY ([<datatype>] [<number> | INTERVAL] '<interval_value>') ]
[ WITH ( <storage_parameter> = <value> [ , ... ] ) ]
[ <storage_directive> [, ...] ]
[ TABLESPACE <tablespace> ]
```

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Description

`CREATE TABLE` creates a new, initially empty table in the current database. The user who issues the command owns the table.

To create a table, you must have `USAGE` privilege on all column types or the type in the `OF` clause, respectively.

If you specify a schema name, WarehousePG creates the table in the specified schema. Otherwise WarehousePG creates the table in the current schema. Temporary tables exist in a special schema, so you cannot specify a schema name when creating a temporary table. The name of the table must be distinct from the name of any other table, external table, sequence, index, view, or foreign table in the same schema.

`CREATE TABLE` also automatically creates a data type that represents the composite type corresponding to one row of the table. Therefore, tables cannot have the same name as any existing data type in the same schema.

The optional constraint clauses specify conditions that new or updated rows must satisfy for an insert or update operation to succeed. A constraint is an SQL object that helps define the set of valid values in the table in various ways.

WarehousePG accepts, but does not enforce, referential integrity (foreign key) constraints. The information is retained in the system catalogs but is otherwise ignored.

You can define two types of constraints: table constraints and column constraints. A column constraint is defined as part of a column definition. A table constraint definition is not tied to a particular column, and it can encompass more than one column. Every column constraint can also be written as a table constraint; a column constraint is only a notational convenience for use when the constraint only affects one column.

When creating a table, you specify an additional clause to declare the WarehousePG distribution policy. If a `DISTRIBUTED BY`, `DISTRIBUTED RANDOMLY`, or `DISTRIBUTED REPLICATED` clause is not supplied, then WarehousePG assigns a hash distribution policy to the table using either the `PRIMARY KEY` (if the table has one) or the first column of the table as the distribution key. Columns of geometric or user-defined data types are not eligible to be a WarehousePG distribution key column. If a table does not have a column of an eligible data type, the rows are distributed based on a random distribution. To ensure an even distribution of data in your WarehousePG cluster, you want to choose a distribution key that is unique for each record, or if that is not possible, then choose `DISTRIBUTED RANDOMLY`.

If you supply the `DISTRIBUTED REPLICATED` clause, WarehousePG distributes all rows of the table to all segments in the WarehousePG cluster. You can use this option in cases where user-defined functions must run on the segments, and the functions require access to all rows of the table. Replicated functions can also be used to improve query performance by preventing broadcast motions for the table. The `DISTRIBUTED REPLICATED` clause cannot be used with the `PARTITION` clauses or the `INHERITS` clause. A replicated table also cannot be inherited by another table. The hidden system columns (`ctid`, `cmin`, `cmax`, `xmin`, `xmax`, and `gp_segment_id`) cannot be referenced in user queries on replicated tables because they have no single, unambiguous value. WarehousePG returns a `column does not exist` error for the query.

`CREATE TABLE` supports coordinator-only distribution via the clause `DISTRIBUTED COORDINATOR ONLY`. However, coordinator-only distribution can't be used with inheritance or partitioning: tables using `INHERITS`, `PARTITION BY`, or `PARTITION OF` can't be defined as coordinator-only.

Coordinator-only distribution is intended for specialized use cases and isn't recommended for general workloads. It exists primarily to support some extensions or system components that need to consult their own metadata tables at a very early stage of query processing, before distributed execution can safely occur.

The `PARTITION BY` and `PARTITION OF` clauses allow you to divide the table into multiple sub-tables (or parts) that, taken together, make up the parent table and share its schema.

> **Note** WarehousePG supports both *classic* and *modern* partitioning syntaxes. Refer to Choosing the Partitioning Syntax for more information, including guidance on selecting the appropriate syntax for a partitioned table.

Parameters

GLOBAL | LOCAL These keywords are present for SQL standard compatibility, but have no effect in WarehousePG and are deprecated.

TEMPORARY | TEMP If specified, the table is created as a temporary table. Temporary tables are automatically dropped at the end of a session, or optionally at the end of the current transaction (see `ON COMMIT`). Existing permanent tables with the same name are not visible to the current session while the temporary table exists, unless they are referenced with schema-qualified names. Any indexes created on a temporary table are automatically temporary as well.

Be sure to perform appropriate vacuum and analyze operations on temporary tables via session SQL commands. For example, if you are going to use a temporary table in complex queries, run `ANALYZE` on the temporary table after it is populated.

UNLOGGED If specified, the table is created as an unlogged table. Data written to unlogged tables is not written to the write-ahead (WAL) log, which makes them considerably faster than ordinary tables. However, the contents of an unlogged table are not replicated to mirror segment instances. Also an unlogged table is not crash-safe: WarehousePG automatically truncates an unlogged table after a crash or unclean shutdown. Any indexes created on an unlogged table are automatically unlogged as well.

IF NOT EXISTS Do not throw an error if a relation with the same name already exists. WarehousePG issues a notice in this case. Note that there is no guarantee that the existing relation is anything like the one that would have been created.

table_name The name (optionally schema-qualified) of the table to be created.

OF type_name Creates a *typed table*, which takes its structure from the specified composite type (name optionally schema-qualified). A typed table is tied to its type; for example, the table will be dropped if the type is dropped with `DROP TYPE ... CASCADE`.

When a typed table is created, the data types of the columns are determined by the underlying composite type and are not specified by the `CREATE TABLE` command. But the `CREATE TABLE` command can add defaults and constraints to the table and can specify storage parameters.

column_name The name of a column to be created in the new table.

data_type The data type of the column. This may include array specifiers. For more information on the data types supported by WarehousePG, refer to theData Types documentation.

For table columns that contain textual data, Specify the data type `VARCHAR` or `TEXT`. Specifying the data type `CHAR` is not recommended. In WarehousePG, the data types `VARCHAR` or `TEXT` handle padding added to the data (space characters added after the last non-space character) as significant characters, the data type `CHAR` does not. See Notes.

COLLATE collation The `COLLATE` clause assigns a collation to the column (which must be of a collatable data type). If not specified, the column data type's default collation is used.

```
> **Note** The WarehousePG query optimizer (GPORCA) supports collation only when all columns in the query use the same collation. If columns in the query use
different collations, then WarehousePG uses the Postgres-based planner.
```

ENCODING (storage_directive [, ...]) For a column, the optional `ENCODING` clause specifies the type of compression and block size for the column data. Valid column storage_directives are `compresstype`, `compresslevel`, and `blocksize`.

This clause is valid only for append-optimized, column-oriented tables.

Column compression settings are inherited from the table level to the partition level to the sub-partition level. The lowest-level settings have priority.

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For more information about using column compression, refer toAdding Column-Level Compression.

blocksize Set to the size, in bytes, for each block in a table. The `blocksize` must be between 8192 and 2097152 bytes, and be a multiple of 8192. The default is 32768.

compresslevel For Zstd compression of append-optimized tables, set to an integer value from 1 (fastest compression) to 19 (highest compression ratio). For zlib compression, the valid range is from 1 to 9. For `RLE_TYPE` , the compression level can be an integer value from 1 (fastest compression) to 4 (highest compression ratio).

compresstype Set to `ZLIB` (the default), `ZSTD` , or `RLE_TYPE` , to specify the type of compression used. The value `NONE` deactivates compression. Zstd provides for both speed or a good compression ratio, tunable with the `compresslevel` option. zlib is provided for backwards-compatibility. Zstd outperforms these compression types on usual workloads. The value `RLE_TYPE` , which is supported only for append-optimized, column-oriented tables, enables the run-length encoding (RLE) compression algorithm. RLE compresses data better than the Zstd or zlib compression algorithms when the same data value occurs in many consecutive rows. For columns of type `BIGINT` , `INTEGER` , `DATE` , `TIME` , or `TIMESTAMP` , delta compression is also applied if the `compresstype` option is set to `RLE_TYPE` compression. The delta compression algorithm is based on the delta between column values in consecutive rows and is designed to improve compression when data is loaded in sorted order or the compression is applied to column data that is in sorted order.

INHERITS (parent_table [, ...]) The optional `INHERITS` clause specifies a list of tables from which the new table automatically inherits all columns. Parent tables can be plain tables or foreign tables.

Use of `INHERITS` creates a persistent relationship between the new child table and its parent table(s). Schema modifications to the parent(s) normally propagate to children as well, and by default the data of the child table is included in scans of the parent(s).

If the same column name exists in more than one parent table, an error is reported unless the data types of the columns match in each of the parent tables. If there is no conflict, then the duplicate columns are merged to form a single column in the new table. If the column name list of the new table contains a column name that is also inherited, the data type must likewise match the inherited column(s), and the column definitions are merged into one. If the new table explicitly specifies a default value for the column, this default overrides any defaults from inherited declarations of the column. Otherwise, any parents that specify default values for the column must all specify the same default, or WarehousePG reports an error.

`CHECK` constraints are merged in essentially the same way as columns: if multiple parent tables or the new table definition contain identically-named `CHECK` constraints, these constraints must all have the same check expression, or an error will be reported. Constraints having the same name and expression will be merged into one copy. A constraint marked `NO INHERIT` in a parent will not be considered. Notice that an unnamed `CHECK` constraint in the new table will never be merged, since a unique name will always be chosen for it.

Column `STORAGE` settings are also copied from parent tables.

If a column in the parent table is an identity column, that property is not inherited. You can declare a column in the child table an identity column if desired.

PARTITION BY { RANGE | LIST | HASH } ({ column_name | (expression) } [opclass][, ...]) The optiona `PARTITION BY` clause of the *modern partitioning syntax* specifies a strategy of partitioning the table. The table thus created is referred to as a partitioned table. The parenthesized list of columns or expressions forms the partition key for the table. When using range or hash partitioning, the partition key can include multiple columns or expressions (up to 32), but for list partitioning, the partition key must consist of a single column or expression.

Range and list partitioning require a btree operator class, while hash partitioning requires a hash operator class. If no operator class is specified explicitly, the default operator class of the appropriate type will be used; if no default operator class exists, WarehousePG raises an error. When hash partitioning is used, the operator class used must implement support function 2 (see Index Method Support Routines in the PostgreSQL documentation for details).

> **Note** Only the modern partitioning syntax supports hash partitions.

A partitioned table is divided into sub-tables (called partitions), which are typically created using separate `CREATE TABLE` commands. The partitioned table is itself empty. A data row inserted into the table is routed to a partition based on the value of columns or expressions in the partition key. If no existing partition matches the values in the new row, WarehousePG reports an error.

Partitioned tables do not support `EXCLUDE` constraints; however, you can define these constraints on individual partitions.

Refer to Partitioning Large Tables for further discussion on table partitioning.

PARTITION OF parent_table { FOR VALUES partition_bound_spec | DEFAULT } The `PARTITION OF` clause of the *modern partitioning syntax* creates the table as a *partition* of the specified parent table. You can create the table either as a partition for specific values using `FOR VALUES` or as a default partition using `DEFAULT` . Any indexes and constraints that exist in the parent table are cloned on the new partition.

The partition_bound_spec must correspond to the partitioning method and partition key of the parent table, and must not overlap with any existing partition of that parent. The form with `IN` is used for list partitioning, the form with `FROM` and `TO` is used for range partitioning, and the form with `WITH` is used for hash partitioning.

partition_bound_expr is any variable-free expression (subqueries, window functions, aggregate functions, and set-returning functions are not allowed). Its data type must match the data type of the corresponding partition key column. The expression is evaluated once at table creation time, so it can even contain volatile expressions such as `CURRENT_TIMESTAMP` .

When creating a list partition, you can specify `NULL` to signify that the partition allows the partition key column to be null. However, there cannot be more than one such list partition for a given parent table. `NULL` cannot be specified for range partitions.

When creating a range partition, the lower bound specified with `FROM` is an inclusive bound, whereas the upper bound specified with `TO` is an exclusive bound. That is, the values specified in the `FROM` list are valid values of the corresponding partition key columns for this partition, whereas those in the `TO` list are not. Note that this statement must be understood according to the rules of row-wise comparison (seeRow Constructor Comparison in the PostgreSQL documentation for more information.). For example, given `PARTITION BY RANGE (x, y)` , a partition bound `FROM (1, 2) TO (3, 4)` allows `x=1` with any `y>=2` , `x=2` with any non-null `y` , and `x=3` with any `y<4` .

The special values `MINVALUE` and `MAXVALUE` may be used when creating a range partition to indicate that there is no lower or upper bound on the column's value. For example, a partition defined using `FROM (MINVALUE) TO (10)` allows any values less than 10, and a partition defined using `FROM (10) TO (MAXVALUE)` allows any values greater than or equal to 10.

When creating a range partition involving more than one column, it can also make sense to use `MAXVALUE` as part of the lower bound, and `MINVALUE` as part of the upper bound. For example, a partition defined using `FROM (0, MAXVALUE) TO (10, MAXVALUE)` allows any rows where the first partition key column is greater than 0 and less than or equal to 10. Similarly, a partition defined using `FROM ('a', MINVALUE) TO ('b', MINVALUE)` allows any rows where the first partition key column starts with "a".

Note that if `MINVALUE` or `MAXVALUE` is used for one column of a partitioning bound, the same value must be used for all subsequent columns. For example, `(10, MINVALUE, 0)` is not a valid bound; you must specify `(10, MINVALUE, MINVALUE)` .

Also note that some element types, such as timestamp, have a notion of "infinity", which is just another value that can be stored. This is different from `MINVALUE` and `MAXVALUE` , which are not real values that can be stored, but rather they are ways of saying that the value is unbounded. `MAXVALUE` can be thought of as being greater than any other value, including "infinity" and `MINVALUE` as being less than any other value, including "minus infinity". Thus the range `FROM ('infinity') TO (MAXVALUE)` is not an empty range; it allows precisely one value to be stored — "infinity".

If `DEFAULT` is specified, the table will be created as the default partition of the parent table. This option is not available for hash-partitioned tables. WarehousePG routes a partition key value not fitting into any other partition of the given parent to the default partition.

When a table has an existing `DEFAULT` partition and a new partition is added to it, the default partition must be scanned to verify that it does not contain any rows which properly belong in the new partition. If the default partition contains a large number of rows, this may be a slow operation. WarehousePG skips the scan if the default partition is a foreign table or if it has a constraint which proves that it cannot contain rows which should be placed in the new partition.

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When creating a hash partition, you must specify a modulus and a remainder. The modulus must be a positive integer, and the remainder must be a non-negative integer less than the modulus. Typically, when initially setting up a hash-partitioned table, you should choose a modulus equal to the number of partitions and assign every table the same modulus and a different remainder (see examples below). However, it is not required that every partition have the same modulus, only that every modulus which occurs among the partitions of a hash-partitioned table is a factor of the next larger modulus. This allows the number of partitions to be increased incrementally without needing to move all the data at once. For example, suppose you have a hash-partitioned table with 8 partitions, each of which has modulus 8, but find it necessary to increase the number of partitions to 16. You can detach one of the modulus-8 partitions, create two new modulus-16 partitions covering the same portion of the key space (one with a remainder equal to the remainder of the detached partition, and the other with a remainder equal to that value plus 8), and repopulate them with data. You can then repeat this -- perhaps at a later time -- for each modulus-8 partition until none remain. While this may still involve a large amount of data movement at each step, it is still preferable to having to create a whole new table and move all the data at once.

A partition must have the same column names and types as the partitioned table to which it belongs. Modifications to the column names or types of a partitioned table automatically propagate to all partitions `CHECK` constraints are inherited automatically by every partition, but an individual partition may specify additional `CHECK` constraints; additional constraints with the same name and condition as in the parent will be merged with the parent constraint. Defaults may be specified separately for each partition. But note that a partition's default value is not applied when inserting a tuple through a partitioned table.

WarehousePG automatically routes rows inserted into a partitioned table to the correct partition. If no suitable partition exists, WarehousePG returns an error.

Operations such as `TRUNCATE` which normally affect a table and all of its inheritance children will cascade to all partitions, but may also be performed on an individual partition. Note that dropping a partition with `DROP TABLE` requires taking an `ACCESS EXCLUSIVE` lock on the parent table.

LIKE source_table [like_option `...`] The `LIKE` clause specifies a table from which the new table automatically copies all column names, their data types, not-null constraints, and distribution policy.

> **Note** Storage properties and the partition structure are *not* copied to the new table.

Unlike `INHERITS`, the new table and original table are completely decoupled after creation is complete. Changes to the original table will not be applied to the new table, and it is not possible to include data of the new table in scans of the original table.

Also unlike `INHERITS`, columns and constraints copied by `LIKE` are not merged with similarly named columns and constraints. If the same name is specified explicitly or in another `LIKE` clause, WarehousePG signals an error.

The optional like_option clauses specify which additional properties of the original table to copy. Specifying `INCLUDING` copies the property, specifying `EXCLUDING` omits the property. `EXCLUDING` is the default. If multiple specifications are made for the same kind of object, the last one is used. The available options are:

INCLUDING AM The access method of the original table will be copied. When you include `AM`, you must not explicitly specify the access method of the new table using the `WITH` or the `USING` clauses.

INCLUDING COMMENTS Comments for the copied columns, constraints, and indexes will be copied. The default behavior is to exclude comments, resulting in the copied columns and constraints in the new table having no comments.

INCLUDING CONSTRAINTS `CHECK` constraints will be copied. No distinction is made between column constraints and table constraints. Not-null constraints are always copied to the new table.

INCLUDING DEFAULTS Default expressions for the copied column definitions will be copied. Otherwise, default expressions are not copied, resulting in the copied columns in the new table having null defaults. Note that copying defaults that call database-modification functions, such as `nextval`, may create a functional linkage between the original and new tables.

INCLUDING ENCODING For an append-optimized, column-oriented original table, copies the per-column encodings.

INCLUDING GENERATED Any generation expressions of copied column definitions will be copied. By default, new columns will be regular base columns.

INCLUDING IDENTITY Any identity specifications of copied column definitions will be copied. A new sequence is created for each identity column of the new table, separate from the sequences associated with the old table.

INCLUDING INDEXES Indexes, `PRIMARY KEY`, `UNIQUE`, and `EXCLUDE` constraints on the original table will be created on the new table. Names for the new indexes and constraints are chosen according to the default rules, regardless of how the originals were named. (This behavior avoids possible duplicate-name failures for the new indexes.)

INCLUDING RELOPT Copies relation storage options from the original table. For append-optimized and append-optimized, column-oriented tables, copies the `blocksize`, `compresslevel`, and `compresstype.` For heap tables, copies the `fillfactor`. You can also specify relation storage parameters. : When you include `RELOPT` options, you must not explicitly specify relation storage options for the new table using the `WITH` clause.

INCLUDING STATISTICS Extended statistics are copied to the new table.

INCLUDING STORAGE `STORAGE` settings for the copied column definitions will be copied. The default behavior is to exclude `STORAGE` settings, resulting in the copied columns in the new table having type-specific default settings.

INCLUDING ALL `INCLUDING ALL` is an abbreviated form of all available options (It may be useful to specify individual `EXCLUDING` clauses after `INCLUDING ALL` to select all but some specific options.)

You can also use the `LIKE` clause to copy column definitions from views, foreign tables, or composite types. WarehousePG ignores inapplicable options (for example, `INCLUDING INDEXES` from a view).

CONSTRAINT constraint_name An optional name for a column or table constraint. If the constraint is violated, the constraint name is present in error messages, so constraint names like `column must be positive` can be used to communicate helpful constraint information to client applications. (Use double-quotes to specify constraint names that contain spaces.) If a constraint name is not specified, the system generates a name.

> **Note** The specified constraint_name is used for the constraint, but a system-generated unique name is used for the index name. In some prior releases, the provided name was used for both the constraint name and the index name.

NOT NULL The column is not allowed to contain null values.

NULL The column is allowed to contain null values. This is the default.

This clause is only provided for compatibility with non-standard SQL databases. Its use is discouraged in new applications.

CHECK (expression) [NO INHERIT] The `CHECK` clause specifies an expression producing a Boolean result which new or updated rows must satisfy for an insert or update operation to succeed. Expressions evaluating to `TRUE` or `UNKNOWN` succeed. Should any row of an insert or update operation produce a `FALSE` result, WarehousePG raises an error exception, and the insert or update does not alter the database. A check constraint specified as a column constraint should reference that column's value only, while an expression appearing in a table constraint can reference multiple columns.

Currently, `CHECK` expressions cannot contain subqueries nor refer to variables other than columns of the current row. You can reference the system column `tableoid`, but not any other system column.

A constraint marked with `NO INHERIT` will not propagate to child tables.

When a table has multiple `CHECK` constraints, they will be tested for each row in alphabetical order by name, after checking `NOT NULL` constraints. (Previous WarehousePG versions did not honor any particular firing order for `CHECK` constraints.)

DEFAULT default_expr The `DEFAULT` clause assigns a default data value for the column whose column definition it appears within. The value is any variable-free expression (in particular, cross-references to other columns in the current table are not allowed). Subqueries are not allowed either. The data type of the default expression must match the data type of the column. The default expression will be used in any insert operation that does not specify a value for the column. If there is no default for a column, then the default is null.

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GENERATED ALWAYS AS (generation_expr) STORED This clause creates the column as a *generated column*. The column cannot be written to, and when read the result of the specified expression will be returned. The keyword `STORED` is required to signify that the column will be computed on write and will be stored on disk. The generation expression can refer to other columns in the table, but not other generated columns. Any functions and operators used must be immutable. References to other tables are not allowed.

GENERATED { ALWAYS | BY DEFAULT } AS IDENTITY [(sequence_options)] This clause creates the column as an identity column. WarehousePG attaches an implicit sequence to it, and automatically assigns a value from the sequence to the column in new rows. Such a column is implicitly `NOT NULL`. The clauses `ALWAYS` and `BY DEFAULT` determine how the sequence value is given precedence over a user-specified value in an `INSERT` statement. If `ALWAYS` is specified, a user-specified value is only accepted if the `INSERT` statement specifies `OVERRIDING SYSTEM VALUE`. If `BY DEFAULT` is specified, then the user-specified value takes precedence. See INSERT for details. (In the `COPY` command, ueser-specified values are always used regardless of this setting.) You can use the optional sequence_options clause to override the options of the sequence. See CREATE SEQUENCE for details.

UNIQUE (column_constraint) UNIQUE (column_name [, ...]) [INCLUDE (column_name [, ...])] (table_constraint) The `UNIQUE` constraint specifies that a group of one or more columns of a table may contain only unique values. The behavior of a unique table constraint is the same as that of a unique column constraint, with the additional capability to span multiple columns. The constraint therefore enforces that any two rows must differ in at least one of these columns.

For the purpose of a unique constraint, null values are not considered equal. The column(s) that are unique must contain all the columns of the WarehousePG distribution key. In addition, the `<key>` must contain all the columns in the partition key if the table is partitioned. Note that a `<key>` constraint in a partitioned table is not the same as a simple `UNIQUE INDEX`.

Each unique constraint should name a set of columns that is different from the set of columns named by any other unique or primary key constraint defined for the table. (Otherwise, WarehousePG discards redundant unique constraints.)

When establishing a unique constraint for a multi-level partition hierarchy, all of the columns in the partition key of the target partitioned table, as well as those of all its descendant partitioned tables, must be included in the constraint definition.

Adding a unique constraint automatically creates a unique btree index on the column or group of columns used in the constraint.

The optional `INCLUDE` clause adds to that index one or more columns that are simply "payload": uniqueness is not enforced on them, and the index cannot be searched on the basis of those columns. However they can be retrieved by an index-only scan. Note that although the constraint is not enforced on included columns, it still depends on them. Consequently, some operations on such columns (for example, `DROP COLUMN`) can cause cascaded constraint and index deletion.

PRIMARY KEY (column constraint) PRIMARY KEY (column_name [, ...]) [INCLUDE (column_name [, ...])] (table constraint) The `PRIMARY KEY` constraint specifies that a column or columns of a table may contain only unique (non-duplicate), non-null values. You can specify only one primary key for a table, whether as a column constraint or a table constraint.

The primary key constraint should name a set of columns that is different from the set of columns named by any unique constraint defined for the same table. (Otherwise, the unique constraint is redundant and will be discarded.)

`PRIMARY KEY` enforces the same data constraints as a combination of `UNIQUE` and `NOT NULL`, but identifying a set of columns as the primary key also provides metadata about the design of the schema, since a primary key implies that other tables can rely on this set of columns as a unique identifier for rows.

When placed on a partitioned table, `PRIMARY KEY` constraints share the restrictions previously described for `UNIQUE` constraints.

Adding a `PRIMARY KEY` constraint will automatically create a unique btree index on the column or group of columns used in the constraint.

The optional `INCLUDE` clause adds to that index one or more columns that are simply "payload": uniqueness is not enforced on them, and the index cannot be searched on the basis of those columns. However they can be retrieved by an index-only scan. Note that although the constraint is not enforced on included columns, it still depends on them. Consequently, some operations on such columns (for example, `DROP COLUMN`) can cause cascaded constraint and index deletion.

EXCLUDE [USING index_method] (exclude_element WITH operator [, ...]) index_parameters [WHERE (predicate)] The `EXCLUDE` clause defines an exclusion constraint, which guarantees that if any two rows are compared on the specified column(s) or expression(s) using the specified operator(s), not all of these comparisons will return `TRUE`. If all of the specified operators test for equality, this is equivalent to a `UNIQUE` constraint, although an ordinary unique constraint will be faster. However, exclusion constraints can specify constraints that are more general than simple equality. For example, you can specify a constraint that no two rows in the table contain overlapping circles by using the `&&` operator.

WarehousePG does not support specifying an exclusion constraint on a randomly-distributed table.

Exclusion constraints are implemented using an index, so each specified operator must be associated with an appropriate operator class for the index access method index_method. The operators are required to be commutative. Each exclude_element can optionally specify an operator class and/or ordering options; these are described fully under CREATE INDEX.

The access method must support `amgettuple`; at present this means GIN cannot be used. Although it's allowed, there is little point in using B-tree or hash indexes with an exclusion constraint, because this does nothing that an ordinary unique constraint doesn't do better. So in practice the access method will always be GiST or SP-GiST.

The predicate allows you to specify an exclusion constraint on a subset of the table; internally this creates a partial index. Note that parentheses are required around the predicate.

REFERENCES reftable [(refcolumn)] [MATCH matchtype] [ON DELETE key_action] [ON UPDATE key_action] (column constraint) FOREIGN KEY (column_name [, ...]) REFERENCES reftable [(refcolumn [, ...])] [MATCH matchtype] [ON DELETE referential_action] [ON UPDATE referential_action] (table constraint) The `REFERENCES` and `FOREIGN KEY` clauses specify referential integrity constraints (foreign key constraints). WarehousePG accepts referential integrity constraints but does not enforce them.

DEFERRABLE NOT DEFERRABLE The `[NOT] DEFERRABLE` clause controls whether the constraint can be deferred. A constraint that is not deferrable will be checked immediately after every command. Checking of constraints that are deferrable can be postponed until the end of the transaction (using the `SET CONSTRAINTS` command). `NOT DEFERRABLE` is the default. Currently, only `UNIQUE`, `PRIMARY KEY`, and `EXCLUDE` constraints accept this clause. `NOT NULL` and `CHECK` constraints are not deferrable. `REFERENCES` (foreign key) constraints accept this clause but are not enforced. Note that deferrable constraints cannot be used as conflict arbitrators in an `INSERT` statement that includes an `ON CONFLICT DO UPDATE` clause.

Note that deferrable constraints cannot be used as conflict arbitrators in an `INSERT` statement that includes an `ON CONFLICT DO UPDATE` clause.

INITIALLY IMMEDIATE INITIALLY DEFERRED If a constraint is deferrable, this clause specifies the default time to check the constraint. If the constraint is `INITIALLY IMMEDIATE`, it is checked after each statement. This is the default. If the constraint is `INITIALLY DEFERRED`, it is checked only at the end of the transaction. You can alter the constraint check time with the SET CONSTRAINTS command.

USING access_method The optional `USING` clause specifies the table access method to use to store the contents for the new table you are creating; the method must be an access method of type `TABLE`. Set to `heap` to access the table as a heap-storage table, `ao_row` to access the table as an append-optimized table with row-oriented storage (AO), or `ao_column` to access the table as an append-optimized table with column-oriented storage (AO/CO). The default access method is determined by the value of the default_table_access_method server configuration parameter.

> **Note**
>
> Although you can specify the table's access method using `WITH (appendoptimized=true|false, orientation=row|column)` it is recomended to use `USING <access_method>` instead.

WITH (storage_parameter=value) The `WITH` clause specifies optional storage parameters for a table or index; see Storage Parameters below for details. For backward-compatibility the `WITH` clause for a table can also include `OIDS=FALSE` to specify that rows of the new table should not contain OIDs (object identifiers), `OIDS=TRUE` is no longer supported.

ON COMMIT You can control the behavior of temporary tables at the end of a transaction block using `ON COMMIT`. The three options are:

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PRESERVE ROWS - No special action is taken at the ends of transactions for temporary tables. This is the default behavior.

DELETE ROWS - All rows in the temporary table will be deleted at the end of each transaction block. Essentially, WarehousePG performs an automaticTRUNCATE at each commit. When used on a partitioned table, this operation is not cascaded to its partitions.

DROP - The temporary table will be dropped at the end of the current transaction block. When used on a partitioned table, this action drops its partitions and when used on tables with inheritance children, it drops the dependent children.

TABLESPACE tablespace The name of the tablespace in which the new table is to be created. If not specified, the database'sdefault_tablespace is consulted, or temp_tablespaces if the table is temporary. For partitioned tables, since no storage is required for the table itself, the tablespace specified overrides `default_tablespace` as the default tablespace to use for any newly created partitions when no other tablespace is explicitly specified.

USING INDEX TABLESPACE tablespace This clause allows selection of the tablespace in which the index associated with a `UNIQUE`, `PRIMARY KEY`, or `EXCLUDE` constraint will be created. If not specified, the database's default_tablespace is used, or temp_tablespaces if the table is temporary.

DISTRIBUTED BY (column [opclass] [, ...]) DISTRIBUTED RANDOMLY DISTRIBUTED REPLICATED DISTRIBUTED COORDINATOR ONLY

Used to declare the WarehousePG distribution policy for the table. `DISTRIBUTED BY` uses hash distribution with one or more columns declared as the distribution key. For the most even data distribution, the distribution key should be the primary key of the table or a unique column (or set of columns). If that is not possible, then you may choose `DISTRIBUTED RANDOMLY`, which will send the data randomly to the segment instances. Additionally, an operator class, `opclass`, can be specified, to use a non-default hash function.

The `DISTRIBUTED COORDINATOR ONLY` clause specifies that the data is located only on the coordinator node. This policy is primarily used for small lookup tables or system components that need early access to metadata during query planning.

The WarehousePG server configuration parameter gp_create_table_random_default_distribution controls the default table distribution policy if the DISTRIBUTED BY clause is not specified when you create a table. WarehousePG follows these rules to create a table if a distribution policy is not specified.

If the value of the parameter is `off` (the default), WarehousePG chooses the table distribution key based on the command:

- If a `LIKE` or `INHERITS` clause is specified, then WarehousePG copies the distribution key from the source or parent table.
- If `PRIMARY KEY`, `UNIQUE`, or `EXCLUDE` constraints are specified, then WarehousePG chooses the largest subset of all the key columns as the distribution key.
- If no constraints nor a `LIKE` or `INHERITS` clause is specified, then WarehousePG chooses the first suitable column as the distribution key. (Columns with geometric or user-defined data types are not eligible as WarehousePG distribution key columns.)

If the value of the parameter is set to `on`, WarehousePG follows these rules:

- If `PRIMARY KEY`, `UNIQUE`, or `EXCLUDE` columns are not specified, the distribution of the table is random (`DISTRIBUTED RANDOMLY`). Table distribution is random even if the table creation command contains the `LIKE` or `INHERITS` clause.
- If `PRIMARY KEY`, `UNIQUE`, or `EXCLUDE` columns are specified, you must also specify a `DISTRIBUTED BY` clause If a `DISTRIBUTED BY` clause is not specified as part of the table creation command, the command fails.

The `DISTRIBUTED REPLICATED` clause replicates the entire table to all WarehousePG segment instances. It can be used when it is necessary to run user-defined functions on segments when the functions require access to all rows in the table, or to improve query performance by preventing broadcast motions.

Classic Partitioning Syntax Parameters

Descriptions of additional parameters that are specific to the *classic partitioning syntax* follow.

> **Note** modern partitioning syntax is the preferred recomendation

CREATE TABLE table_name ... PARTITION BY

When creating a partitioned table using the *classic syntax*, WarehousePG creates the root partitioned table with the specified table name. WarehousePG also creates a hierarchy of tables, child tables, that are the sub-partitions based on the partitioning options that you specify. The pg_partitioned_table system catalog contains information about the sub-partition tables.

classic_partition_spec Declares the individual partitions to create. Each partition can be defined individually or, for range partitions, you can use the `EVERY` clause (with a `START` and optional `END` clause) to define an increment pattern to use to create the individual partitions.

DEFAULT PARTITION name Declares a default partition. When data does not match the bouds of an existing partition, WarehousePG inserts it into the default partition. Partition designs that do not identify a default partition will reject incoming rows that do not match an existing partition.

PARTITION name Declares a name to use for the partition. Partitions are created using the following naming convention: `<table_name>_<level#>_prt_<given_name>`.

VALUES For list partitions, defines the value(s) that the partition will contain.

START For range partitions, defines the starting range value for the partition. By default, start values are `INCLUSIVE`. For example, if you declared a start date of `2016-01-01`', then the partition would contain all dates greater than or equal to '`2016-01-01`'. The data type of the `START` expression must support a suitable `+` operator, for example `timestamp` or `integer` (not `float` or `text`) if it is defined with the `EXCLUSIVE` keyword. Typically the data type of the `START` expression is the same type as the partition key column. If that is not the case, then you must explicitly cast to the intended data type.

END For range partitions, defines the ending range value for the partition. By default, end values are `EXCLUSIVE`. For example, if you declared an end date of `2016-02-01`', then the partition would contain all dates less than but not equal to '`2016-02-01`'. The data type of the `END` expression must support a suitable `+` operator, for example `timestamp` or `integer` (not `float` or `text`) if it is defined with the `INCLUSIVE` keyword. The data type of the `END` expression is typically the same type as the partition key column. If that is not the case, then you must explicitly cast to the intended data type.

EVERY For range partitions, defines how to increment the values from `START` to `END` to create individual partitions. The data type of the `EVERY` expression is typically the same type as the partition key column. If that is not the case, then you must explicitly cast to the intended data type.

WITH Sets the table storage options for a partition. For example, you may want older partitions to be append-optimized tables and newer partitions to be regular heap tables. SeeStorage Parameters, below.

TABLESPACE The name of the tablespace in which the partition is to be created.

SUBPARTITION BY Declares one or more columns by which to sub-partition the first-level partitions of the table. For `LIST` partitioning, the partition key must consist of a single column or expression. The format of the sub-partition specification is similar to that of a partition specification described above.

SUBPARTITION TEMPLATE Instead of declaring each sub-partition definition individually for each partition, you can optionally declare a sub-partition template to be used to create the sub-partitions (lower level child tables). This sub-partition specification would then apply to all parent partitions.

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Storage Parameters

The `WITH` clause can specify storage parameters for tables, and for indexes associated with a `UNIQUE`, `PRIMARY KEY`, or `EXCLUDE` constraint. Storage parameters for indexes are documented on the CREATE INDEX reference page. The storage parameters currently available for tables are listed below. For many of these parameters, as shown, there is an additional parameter with the same name prefixed with `toast.`, which controls the behavior of the table's secondary TOAST table, if any. If a table parameter value is set and the equivalent `toast.` parameter is not, the TOAST table will use the table's parameter value. Specifying these parameters for partitioned tables is not supported, but you may specify them for individual leaf partitions.

Note that you can also set storage parameters for a particular partition or sub-partition by declaring the `WITH` clause in the *classic syntax* partition specification. The lowest-level partition's settings have priority.

You can specify the defaults for some of the table storage options with the server configuration parametergp_default_storage_options. For information about setting default storage options, seeNotes.

> **Note** Because WarehousePG does not permit autovacuuming user tables, it accepts, but does not apply, certain per-table parameter settings as noted below.

The following table storage parameters are available:

analyze_hll_non_part_table Set this storage parameter to `true` to force collection of HLL statistics even if the table is not part of a partitioned table. This is useful if the table will be exchanged or added to a partitioned table, so that the table does not need to be re-analyzed. The default is `false`.

appendoptimized Set to `TRUE` to create the table as an append-optimized table. If `FALSE` or not declared, the table will be created as a regular heap-storage table.

blocksize Set to the size, in bytes, for each block in a table. The `blocksize` must be between 8192 and 2097152 bytes, and be a multiple of 8192. The default is 32768. The `blocksize` option is valid only if the table is append-optimized.

checksum This option is valid only for append-optimized tables. The value `TRUE` is the default and enables CRC checksum validation for append-optimized tables. The checksum is calculated during block creation and is stored on disk. Checksum validation is performed during block reads. If the checksum calculated during the read does not match the stored checksum, the transaction is cancelled. If you set the value to `FALSE` to deactivate checksum validation, checking the table data for on-disk corruption will not be performed.

compresslevel For Zstd compression of append-optimized tables, set to an integer value from 1 (fastest compression) to 19 (highest compression ratio). For zlib compression, the valid range is from 1 to 9. If not declared, the default is 1. For `RLE_TYPE`, the compression level can be an integer value from 1 (fastest compression) to 4 (highest compression ratio).

The `compresslevel` option is valid only if the table is append-optimized.

compresstype Set to `ZLIB` (the default), `ZSTD`, or `RLE_TYPE` to specify the type of compression used. The value `NONE` deactivates compression. Zstd provides for both speed and a good compression ratio, tunable with the `compresslevel` option. zlib is provided for backward compatibility. Zstd outperforms these compression types on usual workloads. The `compresstype` option is only valid if the table is append-optimized.

The value `RLE_TYPE`, which is supported only for append-optimized, column-oriented tables, enables the run-length encoding (RLE) compression algorithm. RLE compresses data better than the Zstd or zlib compression algorithms when the same data value occurs in many consecutive rows.

For columns of type `BIGINT`, `INTEGER`, `DATE`, `TIME`, or `TIMESTAMP`, delta compression is also applied if the `compresstype` option is set to `RLE_TYPE` compression. The delta compression algorithm is based on the delta between column values in consecutive rows and is designed to improve compression when data is loaded in sorted order or the compression is applied to column data that is in sorted order.

For information about using table compression, see Choosing the Table Storage Model in the *WarehousePG Administrator Guide*.

fillfactor The fillfactor for a table is a percentage between 10 and 100. 100 (complete packing) is the default. When a smaller fillfactor is specified, `INSERT` operations pack table pages only to the indicated percentage; the remaining space on each page is reserved for updating rows on that page. This gives `UPDATE` a chance to place the updated copy of a row on the same page as the original, which is more efficient than placing it on a different page. For a table whose entries are never updated, complete packing is the best choice, but in heavily updated tables smaller fillfactors are appropriate. This parameter cannot be set for TOAST tables.

The fillfactor option is valid only for heap tables (tables that specify the `heap` access method or the `appendoptimized=FALSE` storage parameter).

orientation Set to `column` for column-oriented storage, or `row` (the default) for row-oriented storage. This option is only valid if the table is append-optimized. Heap-storage tables can only be row-oriented.

The following parameters are supported for heap tables only:

toast_tuple_target (integer) The `toast_tuple_target` specifies the minimum tuple length required before WarehousePG attempts to compress and/or move long column values into TOAST tables, and is also the target length WarehousePG tries to reduce the length below once toasting begins. This affects columns marked as External (for move), Main (for compression), or Extended (for both) and applies only to new tuples. There is no effect on existing rows. By default this parameter is set to allow at least 4 tuples per block, which with the default blocksize will be 8184 bytes. Valid values are between 128 bytes and the (blocksize - header), by default 8160 bytes. Changing this value may not be useful for very short or very long rows. Note that the default setting is often close to optimal, and it is possible that setting this parameter could have negative effects in some cases. You can not set this parameter for TOAST tables.

parallel_workers (integer) Sets the number of workers that should be used to assist a parallel scan of this table. If not set, WarehousePG determines a value based on the relation size. The actual number of workers chosen by the planner or by utility statements that use parallel scans may be less, for example due to the setting of `max_worker_processes`.

autovacuum_enabled, toast.autovacuum_enabled (boolean) Enables or disables the autovacuum daemon for a particular table. If `true`, the autovacuum daemon will perform automatic `VACUUM` and/or `ANALYZE` operations on this table following the rules discussed in The Autovacuum Daemon in the PostgreSQL documentation. If `false`, WarehousePG does not autovacuum the table, except to prevent transaction ID wraparound. Note that the autovacuum daemon does not run at all (except to prevent transaction ID wraparound) if the autovacuum parameter is `false`; setting individual tables' storage parameters does not override that. So there is seldom much point in explicitly setting this storage parameter to `true`, only to `false`.

vacuum_index_cleanup, toast.vacuum_index_cleanup (boolean) Enables or disables index cleanup when `VACUUM` is run on this table. The default value is `true`. Disabling index cleanup can speed up `VACUUM` very significantly, but may also lead to severely bloated indexes if table modifications are frequent. The `INDEX_CLEANUP` parameter of `VACUUM`, if specified, overrides the value of this option. Setting this to `false` may be useful when you need to run `VACUUM` as quickly as possible, for example to prevent imminent transaction ID wraparound. However, if you do not perform index cleanup regularly, performance may suffer, because as the table is modified, indexes accumulate dead tuples and the table itself accumulates dead line pointers that cannot be removed until index cleanup completes.

vacuum_truncate, toast.vacuum_truncate (boolean) Enables or disables vacuum to attempt to truncate any empty pages at the end of this table. The default value is `true`. If `true`, `VACUUM` and autovacuum truncate the empty pages, and the disk space for the truncated pages is returned to the operating system. Note that the truncation requires an `ACCESS EXCLUSIVE` lock on the table. The `TRUNCATE` parameter of `VACUUM`, if specified, overrides the value of this option.

autovacuum_vacuum_threshold, toast.autovacuum_vacuum_threshold (integer) Per-table value for the autovacuum_vacuum_threshold server configuration parameter.

> **Note** WarehousePG accepts, but does not apply, values for these storage parameters.

autovacuum_vacuum_scale_factor, toast.autovacuum_vacuum_scale_factor (floating point) Per-table value for the autovacuum_vacuum_scale_factor server configuration parameter.

> **Note** WarehousePG accepts, but does not apply, values for these storage parameters.

autovacuum_analyze_threshold (integer) Per-table value for the `autovacuum_analyze_threshold` server configuration parameter.

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autovacuum_analyze_scale_factor (floating point) Per-table value for the `autovacuum_analyze_scale_factor` server configuration parameter.

autovacuum_vacuum_cost_delay, toast.autovacuum_vacuum_cost_delay (floating point) Per-table value for the `autovacuum_vacuum_cost_delay` server configuration parameter.

> **Note** WarehousePG accepts, but does not apply, values for these storage parameters.

autovacuum_vacuum_cost_limit, toast.autovacuum_vacuum_cost_limit (integer) Per-table value for the `autovacuum_vacuum_cost_limit` server configuration parameter.

> **Note** WarehousePG accepts, but does not apply, values for these storage parameters.

autovacuum_freeze_min_age, toast.autovacuum_freeze_min_age (integer) Per-table value for the vacuum_freeze_min_age parameter. Note that autovacuum will ignore per-table `autovacuum_freeze_min_age` parameters that are larger than half of the system-wide `autovacuum_freeze_max_age` setting.

> **Note** WarehousePG accepts, but does not apply, values for these storage parameters.

autovacuum_freeze_max_age, toast.autovacuum_freeze_max_age (integer) Per-table value for the autovacuum_freeze_max_age server configuration parameter. Note that autovacuum will ignore per-table `autovacuum_freeze_max_age` parameters that are larger than the system-wide setting (it can only be set smaller).

> **Note** WarehousePG accepts, but does not apply, values for these storage parameters.

autovacuum_freeze_table_age, toast.autovacuum_freeze_table_age (integer) Per-table value for the `vacuum_freeze_table_age` server configuration parameter.

> **Note** WarehousePG accepts, but does not apply, values for these storage parameters.

autovacuum_multixact_freeze_min_age, toast.autovacuum_multixact_freeze_min_age (integer) Per-table value for the `vacuum_multixact_freeze_min_age` server configuration parameter. Note that autovacuum will ignore per-table `autovacuum_multixact_freeze_min_age` parameters that are larger than half of the system-wide `autovacuum_multixact_freeze_max_age` setting.

> **Note** WarehousePG accepts, but does not apply, values for these storage parameters.

autovacuum_multixact_freeze_max_age, toast.autovacuum_multixact_freeze_max_age (integer) Per-table value for the `autovacuum_multixact_freeze_max_age` server configuration parameter. Note that autovacuum will ignore per-table `autovacuum_multixact_freeze_max_age` parameters that are larger than the system-wide setting (it can only be set smaller).

> **Note** WarehousePG accepts, but does not apply, values for these storage parameters.

autovacuum_multixact_freeze_table_age, toast.autovacuum_multixact_freeze_table_age (integer) Per-table value for the `vacuum_multixact_freeze_table_age` server configuration parameter.

> **Note** WarehousePG accepts, but does not apply, values for these storage parameters.

log_autovacuum_min_duration, toast.log_autovacuum_min_duration (integer) Per-table value for the `log_autovacuum_min_duration` server configuration parameter.

> **Note** WarehousePG accepts, but does not apply, values for these storage parameters.

Notes

WarehousePG automatically creates an index for each unique constraint and primary key constraint to enforce uniqueness, so it is not necessary to create an index explicitly for primary key columns. (See CREATE INDEX for more information.)

Unique constraints and primary keys are not inherited.

You cannot define a table with more than 1600 columns. (In practice, the effective limit is usually lower because of tuple-length constraints.)

The WarehousePG data types `VARCHAR` or `TEXT` handle padding added to the textual data (space characters added after the last non-space character) as significant characters; the data type `CHAR` does not.

In WarehousePG, values of type `CHAR(<n>)` are padded with trailing spaces to the specified width `<n>`. The values are stored and displayed with the spaces. However, the padding spaces are treated as semantically insignificant. When the values are distributed, the trailing spaces are disregarded. The trailing spaces are also treated as semantically insignificant when comparing two values of data type `CHAR`, and the trailing spaces are removed when converting a character value to one of the other string types.

WarehousePG requires certain special conditions for primary key and unique constraints with regards to columns that are the *distribution key* in a WarehousePG table. For a unique constraint to be enforced in WarehousePG, the table must be hash-distributed (not `DISTRIBUTED RANDOMLY`), and the constraint columns must be the same as, or a superset of, the table's distribution key columns.

Replicated tables (`DISTRIBUTED REPLICATED`) can have both `PRIMARY KEY` and `UNIQUE` column constraints.

A primary key constraint is simply a combination of a unique constraint and a not-null constraint.

Foreign key constraints are not supported in WarehousePG.

For inherited tables, unique constraints, primary key constraints, indexes and table privileges are *not* inherited in the current implementation.

For append-optimized tables, `UPDATE` and `DELETE` are not allowed in a repeatable read or serializable transaction and will cause the transaction to end prematurely.

`DECLARE...FOR UPDATE`, and triggers are not supported with append-optimized tables.

`CLUSTER` on append-optimized tables is only supported over B-tree indexes.

GPORCA does not support list partitions with multi-column (composite) partition keys.

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Examples

Create a table named `rank` in the schema named `baby` and distribute the data using the columns `rank` and `year`:

```
CREATE TABLE baby.rank (id int, rank int, year smallint, count int )
DISTRIBUTED BY (rank, year);
```

Create tables named `films` and `distributors` (the primary key will be used as the WarehousePG distribution key by default):

```
CREATE TABLE films (
    code        char(5) CONSTRAINT firstkey PRIMARY KEY,
    title       varchar(40) NOT NULL,
    did         integer NOT NULL,
    date_prod   date,
    kind        varchar(10),
    len         interval hour to minute
);

CREATE TABLE distributors (
    did    integer PRIMARY KEY GENERATED BY DEFAULT AS IDENTITY,
    name   varchar(40) NOT NULL CHECK (name <> '')
);
```

Create a gzip-compressed, append-optimized table:

```
CREATE TABLE sales (txn_id int, qty int, date date)
WITH (appendoptimized=true, compresslevel=5)
DISTRIBUTED BY (txn_id);
```

Create a table with a 2-dimensional array:

```
CREATE TABLE array_int (
    vector  int[][]
);
```

Define a unique table constraint for the table `films`. Unique table constraints can be defined on one or more columns of the table:

```
CREATE TABLE films (
    code        char(5),
    title       varchar(40),
    did         integer,
    date_prod   date,
    kind        varchar(10),
    len         interval hour to minute,
    CONSTRAINT production UNIQUE(date_prod)
);
```

Define a check column constraint:

```
CREATE TABLE distributors (
    did     integer CHECK (did > 100),
    name    varchar(40)
);
```

Define a check table constraint:

```
CREATE TABLE distributors (
    did     integer,
    name    varchar(40),
    CONSTRAINT con1 CHECK (did > 100 AND name <> '')
);
```

Define a primary key table constraint for the table `films`:

```
CREATE TABLE films (
    code        char(5),
    title       varchar(40),
    did         integer,
    date_prod   date,
    kind        varchar(10),
    len         interval hour to minute,
    CONSTRAINT code_title PRIMARY KEY(code,title)
);
```

Define a primary key constraint for table `distributors`. The following two examples are equivalent, the first using the table constraint syntax, the second the column constraint syntax:

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```
CREATE TABLE distributors (
    did     integer,
    name    varchar(40),
    PRIMARY KEY(did)
);

CREATE TABLE distributors (
    did     integer PRIMARY KEY,
    name    varchar(40)
);
```

Assign a literal constant default value for the column name, arrange for the default value of column `did` to be generated by selecting the next value of a sequence object, and make the default value of `modtime` be the time at which the row is inserted:

```
CREATE TABLE distributors (
    name      varchar(40) DEFAULT 'Luso Films',
    did       integer DEFAULT nextval('distributors_serial'),
    modtime   timestamp DEFAULT current_timestamp
);
```

Define two `NOT NULL` column constraints on the table `distributors`, one of which is explicitly given a name:

```
CREATE TABLE distributors (
    did     integer CONSTRAINT no_null NOT NULL,
    name    varchar(40) NOT NULL
);
```

Define a unique constraint for the `name` column:

```
CREATE TABLE distributors (
    did     integer,
    name    varchar(40) UNIQUE
);
```

The same, specified as a table constraint:

```
CREATE TABLE distributors (
    did     integer,
    name    varchar(40),
    UNIQUE(name)
);
```

Create the same table, specifying 70% fill factor for both the table and its unique index:

```
CREATE TABLE distributors (
    did     integer,
    name    varchar(40),
    UNIQUE(name) WITH (fillfactor=70)
)
WITH (fillfactor=70);
```

Create table `cinemas in tablespace` diskvol1`:

```
CREATE TABLE cinemas (
        id serial,
        name text,
        location text
) TABLESPACE diskvol1;
```

Create a composite type and a typed table:

```
CREATE TYPE employee_type AS (name text, salary numeric);

CREATE TABLE employees OF employee_type (
    PRIMARY KEY (name),
    salary WITH OPTIONS DEFAULT 1000
);
```

Modern Partitioning Syntax Examples

Create a range partitioned table:

```
CREATE TABLE measurement (
    logdate         date not null,
    peaktemp        int,
    unitsales       int
) PARTITION BY RANGE (logdate);
```

Create a range partitioned table with multiple columns in the partition key:

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```
CREATE TABLE measurement_year_month (
    logdate         date not null,
    peaktemp        int,
    unitsales       int
) PARTITION BY RANGE (EXTRACT(YEAR FROM logdate), EXTRACT(MONTH FROM logdate));
```

Create a list partitioned table:

```
CREATE TABLE cities (
    city_id      bigserial not null,
    name         text not null,
    population   bigint
) PARTITION BY LIST (left(lower(name), 1));
```

Create a hash partitioned table:

```
CREATE TABLE orders (
    order_id     bigint not null,
    cust_id      bigint not null,
    status       text
) PARTITION BY HASH (order_id);
```

Create partition of a range partitioned table:

```
CREATE TABLE measurement_y2016m07
    PARTITION OF measurement (
    unitsales DEFAULT 0
) FOR VALUES FROM ('2016-07-01') TO ('2016-08-01');
```

Create a few partitions of a range partitioned table with multiple columns in the partition key:

```
CREATE TABLE measurement_ym_older
    PARTITION OF measurement_year_month
    FOR VALUES FROM (MINVALUE, MINVALUE) TO (2016, 11);

CREATE TABLE measurement_ym_y2016m11
    PARTITION OF measurement_year_month
    FOR VALUES FROM (2016, 11) TO (2016, 12);

CREATE TABLE measurement_ym_y2016m12
    PARTITION OF measurement_year_month
    FOR VALUES FROM (2016, 12) TO (2017, 01);

CREATE TABLE measurement_ym_y2017m01
    PARTITION OF measurement_year_month
    FOR VALUES FROM (2017, 01) TO (2017, 02);
```

Create partition of a list partitioned table:

```
CREATE TABLE cities_ab
    PARTITION OF cities (
    CONSTRAINT city_id_nonzero CHECK (city_id != 0)
) FOR VALUES IN ('a', 'b');
```

Create partition of a list partitioned table that is itself further partitioned and then add a partition to it:

```
CREATE TABLE cities_ab
    PARTITION OF cities (
    CONSTRAINT city_id_nonzero CHECK (city_id != 0)
) FOR VALUES IN ('a', 'b') PARTITION BY RANGE (population);

CREATE TABLE cities_ab_10000_to_100000
    PARTITION OF cities_ab FOR VALUES FROM (10000) TO (100000);
```

Create partitions of a hash partitioned table:

```
CREATE TABLE orders_p1 PARTITION OF orders
    FOR VALUES WITH (MODULUS 4, REMAINDER 0);
CREATE TABLE orders_p2 PARTITION OF orders
    FOR VALUES WITH (MODULUS 4, REMAINDER 1);
CREATE TABLE orders_p3 PARTITION OF orders
    FOR VALUES WITH (MODULUS 4, REMAINDER 2);
CREATE TABLE orders_p4 PARTITION OF orders
    FOR VALUES WITH (MODULUS 4, REMAINDER 3);
```

Create a default partition:

```
CREATE TABLE cities_partdef
    PARTITION OF cities DEFAULT;
```

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Classic Partitioning Syntax Examples

Create a simple, single level partitioned table:

```
CREATE TABLE sales (id int, year int, qtr int, c_rank int, code char(1), region text)
DISTRIBUTED BY (id)
PARTITION BY LIST (code)
( PARTITION sales VALUES ('S'),
  PARTITION returns VALUES ('R')
);
```

Create a three level partitioned table that defines sub-partitions without the `SUBPARTITION TEMPLATE` clause:

```
CREATE TABLE sales (id int, year int, qtr int, c_rank int, code char(1), region text)
DISTRIBUTED BY (id)
PARTITION BY LIST (code)
  SUBPARTITION BY RANGE (c_rank)
    SUBPARTITION by LIST (region)

( PARTITION sales VALUES ('S')
   ( SUBPARTITION cr1 START (1) END (2)
      ( SUBPARTITION ca VALUES ('CA') ),
      SUBPARTITION cr2 START (3) END (4)
        ( SUBPARTITION ca VALUES ('CA') ) ),

 PARTITION returns VALUES ('R')
   ( SUBPARTITION cr1 START (1) END (2)
      ( SUBPARTITION ca VALUES ('CA') ),
     SUBPARTITION cr2 START (3) END (4)
        ( SUBPARTITION ca VALUES ('CA') ) )
);
```

Create the same partitioned table as the previous table using the `SUBPARTITION TEMPLATE` clause:

```
CREATE TABLE sales1 (id int, year int, qtr int, c_rank int, code char(1), region text)
DISTRIBUTED BY (id)
PARTITION BY LIST (code)

   SUBPARTITION BY RANGE (c_rank)
     SUBPARTITION TEMPLATE (
     SUBPARTITION cr1 START (1) END (2),
     SUBPARTITION cr2 START (3) END (4) )

     SUBPARTITION BY LIST (region)
       SUBPARTITION TEMPLATE (
       SUBPARTITION ca VALUES ('CA') )

( PARTITION sales VALUES ('S'),
  PARTITION  returns VALUES ('R')
);
```

Create a three level partitioned table using sub-partition templates and default partitions at each level:

```
CREATE TABLE sales (id int, year int, qtr int, c_rank int, code char(1), region text)
DISTRIBUTED BY (id)
PARTITION BY RANGE (year)

  SUBPARTITION BY RANGE (qtr)
    SUBPARTITION TEMPLATE (
    START (1) END (5) EVERY (1),
    DEFAULT SUBPARTITION bad_qtr )

    SUBPARTITION BY LIST (region)
      SUBPARTITION TEMPLATE (
      SUBPARTITION usa VALUES ('usa'),
      SUBPARTITION europe VALUES ('europe'),
      SUBPARTITION asia VALUES ('asia'),
      DEFAULT SUBPARTITION other_regions)

( START (2009) END (2011) EVERY (1),
  DEFAULT PARTITION outlying_years);
```

Compatibility

`CREATE TABLE` command conforms to the SQL standard, with the following exceptions:

Temporary Tables

In the SQL standard, temporary tables are defined just once and automatically exist (starting with empty contents) in every session that needs them. WarehousePG instead requires each session to issue its own `CREATE TEMPORARY TABLE` command for each temporary table to be used. This allows different sessions to use the same temporary table name for different purposes, whereas the standard's approach constrains all instances of a given temporary table name to have the same table structure.

The standard's distinction between global and local temporary tables is not in WarehousePG. WarehousePG will accept the `GLOBAL` and `LOCAL` keywords in a temporary table declaration, but they have no effect and are deprecated.

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If the `ON COMMIT` clause is omitted, the SQL standard specifies that the default behavior as `ON COMMIT DELETE ROWS`. However, the default behavior in WarehousePG is `ON COMMIT PRESERVE ROWS`. The `ON COMMIT DROP` option does not exist in the SQL standard.

Non-Deferred Uniqueness Constraints

When a `UNIQUE` or `PRIMARY KEY` constraint is not deferrable, Greeplum Database checks for uniqueness immediately whenever a row is inserted or modified. The SQL standard states that uniqueness should be enforced only at the end of the statement; this makes a difference when, for example, a single command updates multiple key values. To obtain standard-compliant behavior, declare the constraint as `DEFERRABLE` but not deferred (for example, `INITIALLY IMMEDIATE`). Note that this can be significantly slower than immediate uniqueness checking.

Column Check Constraints

Column Check Constraints — The SQL standard states that `CHECK` column constraints may only refer to the column they apply to; only `CHECK` table constraints may refer to multiple columns. WarehousePG does not enforce this restriction; it treats column and table check constraints alike.

Exclude Constraint — The `EXCLUDE` constraint type is a WarehousePG extension.

NULL Constraint — The `NULL` constraint is a WarehousePG extension to the SQL standard that is included for compatibility with some other database systems (and for symmetry with the `NOT NULL` constraint). Since it is the default for any column, its presence is not required.

Constraint Naming

The SQL standard states that table and domain constraints must have names that are unique across the schema containing the table or domain. WarehousePG is laxer: it only requires constraint names to be unique across the constraints attached to a particular table or domain. However, this extra freedom does not exist for index-based constraints (`UNIQUE`, `PRIMARY KEY`, and `EXCLUDE` constraints), because the associated index is named the same as the constraint, and index names must be unique across all relations within the same schema.

WarehousePG does not currently record names for `NOT NULL` constraints at all, so they are not subject to the uniqueness restriction.

Inheritance

Multiple inheritance via the `INHERITS` clause is a WarehousePG language extension. SQL:1999 and later define single inheritance using a different syntax and different semantics. SQL:1999-style inheritance is not yet supported by WarehousePG.

Zero-Column Tables

WarehousePG allows a table of no columns to be created (for example, `CREATE TABLE foo();`). This is an extension from the SQL standard, which does not allow zero-column tables. Because zero-column tables are not in themselves very useful, disallowing them creates odd special cases for `ALTER TABLE DROP COLUMN`, so WarehousePG ignores this spec restriction.

Multiple Identity Columns

WarehousePG allows a table to have more than one identity column. The standard specifies that a table can have at most one identity column. WarehousePG relaxes this restriction to provide more flexibility for schema changes or migrations. Note that the `INSERT` command supports only one override clause that applies to the entire statement, so having multiple identity columns with different behaviors is not well supported.

Generated Columns

The option `STORED` is not standard but is also used by other SQL implementations. The SQL standard does not specify the storage of generated columns.

LIKE Clause

While a `LIKE` clause exists in the SQL standard, many of the options that WarehousePG accepts for it are not in the standard, and some of the standard's options are not implemented by WarehousePG.

WITH Clause

The `WITH` clause is a WarehousePG extension; storage parameters are in the standard.

Tablespaces

The WarehousePG concept of tablespaces is not part of the SQL standard. The clauses `TABLESPACE` and `USING INDEX TABLESPACE` are extensions.

Typed Tables

Typed tables implement a subset of the SQL standard. According to the standard, a typed table has columns corresponding to the underlying composite type as well as one other column that is the "self-referencing column". WarehousePG does not support self-referencing columns explicitly.

PARTITION BY Clause

Table partitioning via the `PARTITION BY` clause is a WarehousePG extension.

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PARTITION OF Clause

Table partitioning via the `PARTITION OF` clause is a WarehousePG extension.

Data Distribution

The WarehousePG concept of a parallel or distributed database is not part of the SQL standard. The `DISTRIBUTED` clauses are extensions.

See Also

ALTER TABLE, DROP TABLE, CREATE EXTERNAL TABLE, CREATE TABLE AS, CREATE TABLESPACE, CREATE TYPE

Parent topic: SQL Commands

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7.1.81 CREATE TABLE AS

Defines a new table from the results of a query.

Synopsis

```
CREATE [ [ GLOBAL | LOCAL ] { TEMPORARY | TEMP } | UNLOGGED ] TABLE [ IF NOT EXISTS ] <table_name>
        [ (<column_name> [, ...] ) ]
        [ USING <access_method> ]
        [ WITH ( <storage_parameter> [= <value>] [, ... ] ) | WITHOUT OIDS ]
        [ ON COMMIT { PRESERVE ROWS | DELETE ROWS | DROP } ]
        [ TABLESPACE <tablespace_name> ]
        AS <query>
        [ WITH [ NO ] DATA ]
        [ DISTRIBUTED BY ( <column> [<opclass>] [, ... ] )
           | DISTRIBUTED RANDOMLY
           | DISTRIBUTED REPLICATED ]
```

Description

`CREATE TABLE AS` creates a table and fills it with data computed by a SELECT command. The table columns have the names and data types associated with the output columns of the `SELECT`, however you can override the column names by giving an explicit list of new column names.

`CREATE TABLE AS` creates a new table and evaluates the query just once to fill the new table initially. The new table will not track subsequent changes to the source tables of the query.

Parameters

GLOBAL | LOCAL Ignored for compatibility. These keywords are deprecated; refer to CREATE TABLE for details.

TEMPORARY | TEMP If specified, the new table is created as a temporary table. Refer to CREATE TABLE for details.

UNLOGGED If specified, the table is created as an unlogged table. Refer to CREATE TABLE for details.

IF NOT EXISTS Do not throw an error if a relation with the same name already exists; simply issue a notice and leave the table unmodified.

table_name The name (optionally schema-qualified) of the new table to be created.

column_name The name of a column in the new table. If column names are not provided, they are taken from the output column names of the query.

USING access_method The optional `USING` clause specifies the table access method to use to store the contents for the new table you are creating; the method must be an access method of typeTABLE. Set to `heap` to access the table as a heap-storage table, `ao_row` to access the table as an append-optimized table with row-oriented storage (AO), or `ao_column` to access the table as an append-optimized table with column-oriented storage (AO/CO). The default access method is determined by the value of the default_table_access_method server configuration parameter.

> **Note**
>
> Although you can specify the table's access method using `<code>WITH (appendoptimized=true|false, orientation=row|column)</code>` the recomendation is to use `<code>USING <access_method></code>` instead.

WITH (storage_parameter=value) The `WITH` clause specifies optional storage parameters for the new table. Refer to the Storage Parameters section on the `CREATE TABLE` reference page for more information.

ON COMMIT The behavior of temporary tables at the end of a transaction block can be controlled using `ON COMMIT`. The three options are:

PRESERVE ROWS — WarehousePG takes no special action at the ends of transactions for temporary tables. This is the default behavior.

DELETE ROWS — WarehousePG deletes all rows in the temporary table at the end of each transaction block. Essentially, an automatic TRUNCATE is done at each commit.

DROP — WarehousePG drops the temporary table at the end of the current transaction block.

TABLESPACE tablespace_name The tablespace_name parameter is the name of the tablespace in which the new table is to be created. If not specified, the database'sdefault_tablespace is used, or temp_tablespaces if the table is temporary.

AS query A SELECT, TABLE, or VALUES command, or an EXECUTE command that runs a prepared `SELECT`, `TABLE`, or `VALUES` query.

DISTRIBUTED BY (column [opclass] [, ...]) DISTRIBUTED RANDOMLY DISTRIBUTED REPLICATED Used to declare the WarehousePG distribution policy for the table. Refer toCREATE TABLE for details.

Notes

This command is functionally similar to SELECT INTO, but it is preferred since it is less likely to be confused with other uses of the `SELECT INTO` syntax. Furthermore, `CREATE TABLE AS` offers a superset of the functionality offered by `SELECT INTO`.

`CREATE TABLE AS` can be used for fast data loading from external table data sources. See CREATE EXTERNAL TABLE.

`CREATE TABLE AS` does not support setting distribution to `COORDINATOR ONLY`.

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Examples

Create a new table `films_recent` consisting of only recent entries from the table `films`:

```
CREATE TABLE films_recent AS
  SELECT * FROM films WHERE date_prod >= '2020-01-01';
```

To copy a table completely, you can also use the short form by specifying the `TABLE` command:

```
CREATE TABLE films2 AS
  TABLE films;
```

Create a new temporary table `films_recent`, consisting only of recent entries from the table `films`, using a prepared statement. The new table will be dropped at commit:

```
PREPARE recentfilms(date) AS
  SELECT * FROM films WHERE date_prod > $1;
CREATE TEMP TABLE films_recent ON COMMIT DROP AS
  EXECUTE recentfilms('2020-01-01');
```

Compatibility

`CREATE TABLE AS` conforms to the SQL standard, with the following exceptions:

- The standard requires parentheses around the subquery clause; in WarehousePG, these parentheses are optional.
- In the standard, the `WITH [NO] DATA` clause is required, in WarehousePG it is optional.
- WarehousePG handles temporary tables differently from the standard; see CREATE TABLE for details.
- The `WITH` clause is a WarehousePG extension; storage parameters are not part of the standard.
- The WarehousePG concept of tablespaces is not part of the standard. The `TABLESPACE` clause is an extension.

See Also

CREATE EXTERNAL TABLE, CREATE MATERIALIZED VIEW, CREATE TABLE, EXECUTE, SELECT, SELECT INTO, VALUES

Parent topic: SQL Commands

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7.1.82 CREATE TABLESPACE

Defines a new tablespace.

Synopsis

```
CREATE TABLESPACE <tablespace_name>
   [ OWNER { <owner_name> | CURRENT_USER | SESSION_USER } ]
   LOCATION '<directory>'
   [ WITH (content<ID_1>='<directory>'[, content<ID_2>='<directory>' ... ] [, <tablespace_option = value [, ... ] ] ) ]
```

Description

`CREATE TABLESPACE` registers and configures a new tablespace for your WarehousePG cluster. The tablespace name must be distinct from the name of any existing tablespace in the system. A tablespace is a WarehousePG cluster object (a global object), you can use a tablespace from any database if you have appropriate privileges.

A tablespace allows superusers to define an alternative host file system location where the data files containing database objects (such as tables and indexes) reside.

A user with appropriate privileges can pass tablespace_name to CREATE DATABASE, CREATE TABLE, or CREATE INDEX to direct WarehousePG to store the data files for these objects within the specified tablespace.

In WarehousePG, the file system location must exist on all hosts including the hosts running the coordinator, standby mirror, each primary segment, and each mirror segment.

Parameters

tablespace*name The name of a tablespace to be created. The name cannot begin with `pg*`or`gp_`, as such names are reserved for system tablespaces.

owner_name The name of the user who will own the tablespace. If omitted, defaults to the user running the command. Only superusers can create tablespaces, but they can assign ownership of tablespaces to non-superusers.

LOCATION 'directory' The directory that will be used for the tablespace. The directory should be empty and must be owned by the WarehousePG cluster user. You must specify the absolute path of the directory, and the path name must not be greater than 100 characters in length. (The location is used to create a symlink target in the pg_tblspc directory, and symlink targets are truncated to 100 characters when sending to `tar` from utilities such as `pg_basebackup`.)

You can specify a different tablespace directory for any WarehousePG segment instance in the `WITH` clause.

contentID_i='directory_i' The value ID_i is the content ID for the segment instance. directory_i is the absolute path to the host system file location that the segment instance uses as the root directory for the tablespace. You cannot specify the content ID of the coordinator instance (`-1`). You can specify the same directory for multiple segments.

If a segment instance is not listed in the `WITH` clause, WarehousePG uses the tablespace directory specified in the `LOCATION` clause.

The restrictions identified for the `LOCATION` directory also hold for directory_i.

tablespace_option A tablespace parameter to set or reset. Currently, the only available parameters are `seq_page_cost` and `random_page_cost`. Setting either value for a particular tablespace will override the planner's usual estimate of the cost of reading pages from tables in that tablespace, as established by the configuration parameters of the same name (see seq_page_cost, random_page_cost). This may be useful if one tablespace is located on a disk which is faster or slower than the remainder of the I/O subsystem.

Notes

Because `CREATE TABLESPACE` creates symbolic links from the `pg_tblspc` directory in the coordinator and segment instance data directory to the directories specified in the command, WarehousePG supports tablespaces only on systems that support symbolic links.

You cannot run `CREATE TABLESPACE` inside a transaction block.

When creating tablespaces, ensure that file system locations have sufficient I/O speed and available disk space.

> **Note** WarehousePG does not support different tablespace locations for a primary-mirror pair with the same content ID. It is only possible to configure different locations for different content IDs. Do not modify symbolic links under the `pg_tblspc` directory so that primary-mirror pairs point to different file locations; this will lead to erroneous behavior.

Examples

Create a new tablespace and specify the file system location for the coordinator and all segment instances:

```
CREATE TABLESPACE mytblspace LOCATION '/gpdbtspc/mytestspace';
```

Create a tablespace `indexspace` at `/data/indexes` owned by user `genevieve`:

```
CREATE TABLESPACE indexspace OWNER genevieve LOCATION '/data/indexes';
```

Create a new tablespace and specify a location for segment instances with content ID 0 and 1. For the coordinator and segment instances not listed in the `WITH` clause, the file system location for the tablespace is the directory specified in the `LOCATION` clause.

```
CREATE TABLESPACE mytblspace LOCATION '/gpdbtspc/mytestspace' WITH (content0='/temp/mytest', content1='/temp/mytest');
```

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The example specifies the same location for the two segment instances. You can a specify different location for each segment.

Compatibility

`CREATE TABLESPACE` is a WarehousePG extension.

See Also

CREATE DATABASE, CREATE TABLE, CREATE INDEX, DROP TABLESPACE, ALTER TABLESPACE

Parent topic: SQL Commands

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7.1.83 CREATE TEXT SEARCH CONFIGURATION

Defines a new text search configuration.

Synopsis

```
CREATE TEXT SEARCH CONFIGURATION <name> (
    PARSER = <parser_name> |
    COPY = <source_config>
)
```

Description

`CREATE TEXT SEARCH CONFIGURATION` creates a new text search configuration. A text search configuration specifies a text search parser that can divide a string into tokens, plus dictionaries that can be used to determine which tokens are of interest for searching.

If only the parser is specified, then the new text search configuration initially has no mappings from token types to dictionaries, and therefore will ignore all words. SubsequentALTER TEXT SEARCH CONFIGURATION commands must be used to create mappings to make the configuration useful. Alternatively, an existing text search configuration can be copied.

If a schema name is provided then the text search configuration is created in the specified schema. Otherwise it is created in the current schema.

The user who defines a text search configuration becomes its owner.

Refer to Using Full Text Search for further information.

Parameters

name The name of the text search configuration to be created. The name can be schema-qualified.

parser_name The name of the text search parser to use for this configuration.

source_config The name of an existing text search configuration to copy.

Notes

The `PARSER` and `COPY` options are mutually exclusive, because when an existing configuration is copied, its parser selection is copied too.

Compatibility

There is no `CREATE TEXT SEARCH CONFIGURATION` statement in the SQL standard.

See Also

ALTER TEXT SEARCH CONFIGURATION, DROP TEXT SEARCH CONFIGURATION

Parent topic: SQL Commands

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7.1.84 CREATE TEXT SEARCH DICTIONARY

Defines a new text search dictionary.

Synopsis

```
CREATE TEXT SEARCH DICTIONARY <name> (
    TEMPLATE = <template>
    [, <option> = <value> [, ... ]]
)
```

Description

CREATE TEXT SEARCH DICTIONARY creates a new text search dictionary. A text search dictionary specifies a way of recognizing interesting or uninteresting words for searching. A dictionary depends on a text search template, which specifies the functions that actually perform the work. Typically the dictionary provides some options that control the detailed behavior of the template's functions.

If a schema name is given then the text search dictionary is created in the specified schema. Otherwise it is created in the current schema.

The user who defines a text search dictionary becomes its owner.

Refer to Using Full Text Search for further information.

Parameters

name The name of the text search dictionary to be created. The name can be schema-qualified.

template The name of the text search template that will define the basic behavior of this dictionary.

option The name of a template-specific option to be set for this dictionary.

value The value to use for a template-specific option. If the value is not a simple identifier or number, it must be quoted (but you can always quote it, if you wish).

The options can appear in any order.

Examples

The following example command creates a Snowball-based dictionary with a nonstandard list of stop words.

```
CREATE TEXT SEARCH DICTIONARY my_russian (
    template = snowball,
    language = russian,
    stopwords = myrussian
);
```

Compatibility

There is no `CREATE TEXT SEARCH DICTIONARY` statement in the SQL standard.

See Also

ALTER TEXT SEARCH DICTIONARY, DROP TEXT SEARCH DICTIONARY

Parent topic: SQL Commands

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7.1.85 CREATE TEXT SEARCH PARSER

Defines a new text search parser.

Synopsis

```
CREATE TEXT SEARCH PARSER <name> (
    START = <start_function> ,
    GETTOKEN = <gettoken_function> ,
    END = <end_function> ,
    LEXTYPES = <lextypes_function>
    [, HEADLINE = <headline_function> ]
)
```

Description

`CREATE TEXT SEARCH PARSER` creates a new text search parser. A text search parser defines a method for splitting a text string into tokens and assigning types (categories) to the tokens. A parser is not particularly useful by itself, but must be bound into a text search configuration along with some text search dictionaries to be used for searching.

If a schema name is given then the text search parser is created in the specified schema. Otherwise it is created in the current schema.

You must be a superuser to use `CREATE TEXT SEARCH PARSER`. (This restriction is made because an erroneous text search parser definition could confuse or even crash the server.)

Refer to Using Full Text Search for further information.

Parameters

name The name of the text search parser to be created. The name can be schema-qualified.

start_function The name of the start function for the parser.

gettoken_function The name of the get-next-token function for the parser.

end_function The name of the end function for the parser.

lextypes_function The name of the lextypes function for the parser (a function that returns information about the set of token types it produces).

headline_function The name of the headline function for the parser (a function that summarizes a set of tokens).

The function names can be schema-qualified if necessary. Argument types are not given, since the argument list for each type of function is predetermined. All except the headline function are required.

The arguments can appear in any order, not only the one shown above.

Compatibility

There is no `CREATE TEXT SEARCH PARSER` statement in the SQL standard.

See Also

ALTER TEXT SEARCH PARSER, DROP TEXT SEARCH PARSER

Parent topic: SQL Commands

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7.1.86 CREATE TEXT SEARCH TEMPLATE

Defines a new text search template.

Synopsis

```
CREATE TEXT SEARCH TEMPLATE <name> (
    [ INIT = <init_function> , ]
    LEXIZE = <lexize_function>
)
```

Description

`CREATE TEXT SEARCH TEMPLATE` creates a new text search template. Text search templates define the functions that implement text search dictionaries. A template is not useful by itself, but must be instantiated as a dictionary to be used. The dictionary typically specifies parameters to be given to the template functions.

If a schema name is given then the text search template is created in the specified schema. Otherwise it is created in the current schema.

You must be a superuser to use `CREATE TEXT SEARCH TEMPLATE`. This restriction is made because an erroneous text search template definition could confuse or even crash the server. The reason for separating templates from dictionaries is that a template encapsulates the "unsafe" aspects of defining a dictionary. The parameters that can be set when defining a dictionary are safe for unprivileged users to set, and so creating a dictionary need not be a privileged operation.

Refer to Using Full Text Search for further information.

Parameters

name The name of the text search template to be created. The name can be schema-qualified.

init_function The name of the init function for the template.

lexize_function The name of the lexize function for the template.

The function names can be schema-qualified if necessary. Argument types are not given, since the argument list for each type of function is predetermined. The lexize function is required, but the init function is optional.

The arguments can appear in any order, not only the order shown above.

Compatibility

There is no `CREATE TEXT SEARCH TEMPLATE` statement in the SQL standard.

See Also

DROP TEXT SEARCH TEMPLATE, ALTER TEXT SEARCH TEMPLATE

Parent topic: SQL Commands

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7.1.87 CREATE TRANSFORM

Defines a new transform

Synopsis

```
CREATE [ OR REPLACE ] TRANSFORM FOR <type_name> LANGUAGE <lang_name> (
  FROM SQL WITH FUNCTION <from_sql_function_name> [ (<argument_type> [, ...]) ],
  TO SQL WITH FUNCTION <to_sql_function_name> [ (<argument_type> [, ...]) ]
);
```

Description

`CREATE TRANSFORM` defines a new transform. `CREATE OR REPLACE TRANSFORM` will either create a new transform, or replace an existing definition.

A transform specifies how to adapt a data type to a procedural language. For example, when writing a function in PL/Python using the `hstore` type, PL/Python has no prior knowledge how to present `hstore` values in the Python environment. Language implementations usually default to using the text representation, but that is inconvenient when, for example, an associative array or a list would be more appropriate.

A transform specifies two functions:

- A "from SQL" function that converts the type from the SQL environment to the language. This function will be invoked on the arguments of a function written in the language.
- A "to SQL" function that converts the type from the language to the SQL environment. This function will be invoked on the return value of a function written in the language.

It is not necessary to provide both of these functions. If one is not specified, the language-specific default behavior will be used if necessary. (To prevent a transformation in a certain direction from happening at all, you could also write a transform function that always errors out.)

To create a transform, you must own and have `USAGE` privilege on the type, have `USAGE` privilege on the language, and own and have `EXECUTE` privilege on the from-SQL and to-SQL functions, if specified.

Parameters

type_name The name of the data type of the transform.

lang_name The name of the language of the transform.

from_sql_function_name[(argument_type [, ...])] The name of the function for converting the type from the SQL environment to the language. It must take a single argument of type `internal` and return type `internal`. The actual argument will be of the type for the transform, and the function should be coded as if it were. (An SQL-level function returning `internal` must declare at least one argument of type `internal`.) The actual return value will be something specific to the language implementation. If no argument list is specified, the function name must be unique in its schema.

to_sql_function_name[(argument_type [, ...])] The name of the function for converting the type from the language to the SQL environment. It must take a single argument of type `internal` and return the type that is the type for the transform. The actual argument value will be something specific to the language implementation. If no argument list is specified, the function name must be unique in its schema.

Notes

Use DROP TRANSFORM to remove transforms.

Examples

To create a transform for type `hstore` and language `plpython3u`, first set up the type and the language:

```
CREATE EXTENSION IF NOT EXISTS hstore;

CREATE EXTENSION
plpython3u;
```

Then create the necessary functions:

```
CREATE FUNCTION hstore_to_plpython(val internal) RETURNS
internal
LANGUAGE C STRICT
IMMUTABLE
AS ...;

CREATE FUNCTION plpython_to_hstore(val internal) RETURNS
hstore
LANGUAGE C STRICT
IMMUTABLE
AS ...;
```

And finally create the transform to connect them all together:

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```
CREATE TRANSFORM FOR hstore LANGUAGE plpython3u
(
    FROM SQL WITH FUNCTION
hstore_to_plpython(internal),
    TO SQL WITH FUNCTION
plpython_to_hstore(internal)
);
```

In practice, these commands would be wrapped up in an extension.

Compatibility

This form of `CREATE TRANSFORM` is a WarehousePG extension. There is a `CREATE TRANSFORM` command in the SQL standard, but it is for adapting data types to client languages. That usage is not supported by WarehousePG.

See Also

CREATE FUNCTION, CREATE LANGUAGE, CREATE TYPE, DROP TRANSFORM

Parent topic: SQL Commands

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7.1.88 CREATE TYPE

Defines a new data type.

Synopsis

```
CREATE TYPE <name> AS
    ( [ <attribute_name> <data_type> [ COLLATE <collation> ] [, ... ] ] )

CREATE TYPE <name> AS ENUM
    ( [ '<label>' [, ... ] ] )

CREATE TYPE <name> AS RANGE (
    SUBTYPE = <subtype>
    [ , SUBTYPE_OPCLASS = <subtype_operator_class> ]
    [ , COLLATION = <collation> ]
    [ , CANONICAL = <canonical_function> ]
    [ , SUBTYPE_DIFF = <subtype_diff_function> ]
)

CREATE TYPE <name> (
    INPUT = <input_function>,
    OUTPUT = <output_function>
    [, RECEIVE = <receive_function>]
    [, SEND = <send_function>]
    [, TYPMOD_IN = <type_modifier_input_function> ]
    [, TYPMOD_OUT = <type_modifier_output_function> ]
    [, ANALYZE = <analyze_function>]
    [, INTERNALLENGTH = {<internallength> | VARIABLE}]
    [, PASSEDBYVALUE]
    [, ALIGNMENT = <alignment>]
    [, STORAGE = <storage>]
    [, LIKE = <like_type>
    [, CATEGORY = <category>]
    [, PREFERRED = <preferred>]
    [, DEFAULT = <default>]
    [, ELEMENT = <element>]
    [, DELIMITER = <delimiter>]
    [, COLLATABLE = <collatable>]
    [, COMPRESSTYPE = <compression_type>]
    [, COMPRESSLEVEL = <compression_level>]
    [, BLOCKSIZE = <blocksize>] )

CREATE TYPE <name>
```

Description

`CREATE TYPE` registers a new data type for use in the current database. The user who defines a type becomes its owner.

If a schema name is given then the type is created in the specified schema. Otherwise it is created in the current schema. The type name must be distinct from the name of any existing type or domain in the same schema. The type name must also be distinct from the name of any existing table in the same schema.

There are five forms of `CREATE TYPE`, as shown in the syntax synopsis above. They respectively create a *composite type*, an *enum type*, a *range type*, a *base type*, or a *shell type*. The first four of these are discussed in turn below. A shell type is simply a placeholder for a type to be defined later; it is created by issuing `CREATE TYPE` with no parameters except for the type name. Shell types are needed as forward references when creating range types and base types, as discussed in those sections.

Composite Types

The first form of `CREATE TYPE` creates a composite type. The composite type is specified by a list of attribute names and data types. An attribute's collation can be specified too, if its data type is collatable. A composite type is essentially the same as the row type of a table, but using `CREATE TYPE` avoids the need to create an actual table when all that is wanted is to define a type. A stand-alone composite type is useful, for example, as the argument or return type of a function.

To create a composite type, you must have `USAGE` privilege on all attribute types.

Enumerated Types

The second form of `CREATE TYPE` creates an enumerated (`ENUM`) type, as described in Enumerated Types in the PostgreSQL documentation. `ENUM` types take a list of quoted labels, each of which must be less than `NAMEDATALEN` bytes long (64).

It is possible to create an enumerated type with zero labels, but such a type cannot be used to hold values before at least one label is added using ALTER TYPE.

Range Types

The third form of `CREATE TYPE` creates a new range type, as described in Range Types.

The range type's subtype can be any type with an associated b-tree operator class (to determine the ordering of values for the range type). Normally the subtype's default b-tree operator class is used to determine ordering; to use a non-default operator class, specify its name with subtype_opclass. If the subtype is collatable, and you want to use a non-default collation in the range's ordering, specify the desired collation with the collation option.

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The optional canonical function must take one argument of the range type being defined, and return a value of the same type. This is used to convert range values to a canonical form, when applicable. SeeDefining New Range Types for more information. Creating a canonical function is a bit tricky, since it must be defined before the range type can be declared. To do this, you must first create a shell type, which is a placeholder type that has no properties except a name and an owner. This is done by issuing the command `CREATE TYPE name`, with no additional parameters. Then the function can be declared using the shell type as argument and result, and finally the range type can be declared using the same name. This automatically replaces the shell type entry with a valid range type.

The optional subtype_diff_function must take two values of the subtype type as argument, and return a double precision value representing the difference between the two given values. While this is optional, providing it allows much greater efficiency of GiST indexes on columns of the range type. See Defining New Range Types for more information.

Base Types

The fourth form of `CREATE TYPE` creates a new base type (scalar type). You must be a superuser to create a new base type. (This restriction is in place because an erroneous type definition could confuse or even crash the server.)

The parameters may appear in any order, not only that shown in the syntax, and most are optional. You must register two or more functions (using `CREATE FUNCTION`) before defining the type. The support functions input_function and output_function are required, while the functions receive_function, send_function, type_modifier_input_function, type_modifier_output_function, and analyze_function are optional. Generally these functions have to be coded in C or another low-level language. In WarehousePG, any function used to implement a data type must be defined as `IMMUTABLE`.

The input_function converts the type's external textual representation to the internal representation used by the operators and functions defined for the type. output_function performs the reverse transformation. The input function may be declared as taking one argument of type `cstring`, or as taking three arguments of types `cstring`, `oid`, `integer`. The first argument is the input text as a C string, the second argument is the type's own OID (except for array types, which instead receive their element type's OID), and the third is the `typmod` of the destination column, if known (`-1` will be passed if not). The input function must return a value of the data type itself. Usually, an input function should be declared `STRICT`; if it is not, it will be called with a `NULL` first parameter when reading a `NULL` input value. The function must still return `NULL` in this case, unless it raises an error. (This case is mainly meant to support domain input functions, which may need to reject `NULL` inputs.) The output function must be declared as taking one argument of the new data type. The output function must return type `cstring`. Output functions are not invoked for `NULL` values.

The optional receive_function converts the type's external binary representation to the internal representation. If this function is not supplied, the type cannot participate in binary input. The binary representation should be chosen to be cheap to convert to internal form, while being reasonably portable. (For example, the standard integer data types use network byte order as the external binary representation, while the internal representation is in the machine's native byte order.) The receive function should perform adequate checking to ensure that the value is valid. The receive function may be declared as taking one argument of type `internal`, or as taking three arguments of types `internal`, `oid`, `integer`. The first argument is a pointer to a `StringInfo` buffer holding the received byte string; the optional arguments are the same as for the text input function. The receive function must return a value of the data type itself. Usually, a receive function should be declared `STRICT`; if it is not, it will be called with a `NULL` first parameter when reading a NULL input value. The function must still return `NULL` in this case, unless it raises an error. (This case is mainly meant to support domain receive functions, which may need to reject `NULL` inputs.) Similarly, the optional send_function converts from the internal representation to the external binary representation. If this function is not supplied, the type cannot participate in binary output. The send function must be declared as taking one argument of the new data type. The send function must return type `bytea`. Send functions are not invoked for `NULL` values.

How can the input and output functions be declared to have results or arguments of the new type, when they have to be created before the new type can be created? The type should first be defined as a shell type, which is a placeholder type that has no properties except a name and an owner. This is done by issuing the command `CREATE TYPE name`, with no additional parameters. Then the I/O functions can be defined referencing the shell type. Finally, `CREATE TYPE` with a full definition replaces the shell entry with a complete, valid type definition, after which the new type can be used normally.

The optional type_modifier_input_function and type_modifier_output_function are required if the type supports modifiers. Modifiers are optional constraints attached to a type declaration, such as `char(5)` or `numeric(30,2)`. While WarehousePG allows user-defined types to take one or more simple constants or identifiers as modifiers, this information must fit into a single non-negative integer value for storage in the system catalogs. WarehousePG passes the declared modifier(s) to the type_modifier_input_function in the form of a `cstring` array. The modifier input function must check the values for validity, throwing an error if they are incorrect. If the values are correct, the modifier input function returns a single non-negative integer value that WarehousePG stores as the column `typmod`. Type modifiers are rejected if the type was not defined with a type_modifier_input_function. The type_modifier_output_function converts the internal integer `typmod` value back to the correct form for user display. The modifier output function must return a `cstring` value that is the exact string to append to the type name. For example, `numeric`'s function might return `(30,2)`. The type_modifier_output_function is optional. When not specified, the default display format is the stored `typmod` integer value enclosed in parentheses.

The optional analyze_function performs type-specific statistics collection for columns of the data type. By default, `ANALYZE` attempts to gather statistics using the type's "equals" and "less-than" operators, if there is a default b-tree operator class for the type. For non-scalar types this behavior is likely to be unsuitable, so it can be overridden by specifying a custom analysis function. The analysis function must be declared to take a single argument of type `internal`, and return a `boolean` result.

While the details of the new type's internal representation are only known to the I/O functions and other functions you create to work with the type, there are several properties of the internal representation that must be declared to WarehousePG. Foremost of these is internallength. Base data types can be fixed-length, in which case internallength is a positive integer, or variable length, indicated by setting internallength to `VARIABLE`. (Internally, this is represented by setting `typlen` to `-1`.) The internal representation of all variable-length types must start with a 4-byte integer giving the total length of this value of the type.

The optional flag `PASSEDBYVALUE` indicates that values of this data type are passed by value, rather than by reference. You may not pass by value types whose internal representation is larger than the size of the `Datum` type (4 bytes on most machines, 8 bytes on a few).

The alignment parameter specifies the storage alignment required for the data type. The allowed values equate to alignment on 1, 2, 4, or 8 byte boundaries. Note that variable-length types must have an alignment of at least 4, since they necessarily contain an `int4` as their first component.

The storage parameter allows selection of storage strategies for variable-length data types. (Only `plain` is allowed for fixed-length types.) `plain` specifies that data of the type will always be stored in-line and not compressed. `extended` specifies that the system will first try to compress a long data value, and will move the value out of the main table row if it's still too long. `external` allows the value to be moved out of the main table, but the system will not try to compress it. `main` allows compression, but discourages moving the value out of the main table. (Data items with this storage strategy may still be moved out of the main table if there is no other way to make a row fit, but they will be kept in the main table preferentially over `extended` and `external` items.)

All storage values other than `plain` imply that the functions of the data type can handle values that have been toasted as described inTOAST and TOAST CONSIDERATIONS in the PostgreSQL documentation. The specific other value given merely determines the default TOAST storage strategy for columns of a toastable data type; users can pick other strategies for individual columns using `ALTER TABLE SET STORAGE`.

The like_type parameter provides an alternative method for specifying the basic representation properties of a data type: copy them from some existing type. The values `internallength`, `passedbyvalue`, `alignment`, and `storage` are copied from the named type. (It is possible, though usually undesirable, to override some of these values by specifying them along with the `LIKE` clause.) Specifying representation this way is especially useful when the low-level implementation of the new type "piggybacks" on an existing type in some fashion.

The *category* and *preferred* parameters can be used to help control which implicit cast WarehousePG applies in ambiguous situations. Each data type belongs to a category named by a single ASCII character, and each type is either "preferred" or not within its category. The parser will prefer casting to preferred types (but only from other types within the same category) when this rule helps resolve overloaded functions or operators. For types that have no implicit casts to or from any other types, it is sufficient to retain the default settings. However, for a group of related types that have implicit casts, it is often helpful to mark them all as belonging to a category and select one or two of the "most general" types as being preferred within the category. The *category* parameter is especially useful when you add a user-defined type to an existing built-in category, such as the numeric or string types. It is also possible to create new entirely-user-defined type categories. Select any ASCII character other than an upper-case letter to name such a category.

A default value may be specified, in case a user wants columns of the data type to default to something other than the null value. Specify the default with the `DEFAULT` key word. (Such a default may be overridden by an explicit `DEFAULT` clause attached to a particular column.)

To indicate that a type is an array, specify the type of the array elements using the `ELEMENT` key word. For example, to define an array of 4-byte integers (int4), specify `ELEMENT = int4`. More details about array types appear below.

To indicate the delimiter to be used between values in the external representation of arrays of this type, `delimiter` can be set to a specific character. The default delimiter is the comma (,). Note that the delimiter is associated with the array element type, not the array type itself.

If the optional Boolean parameter collatable is true, column definitions and expressions of the type may carry collation information through use of the `COLLATE` clause. It is up to the implementations of the functions operating on the type to actually make use of the collation information; this does not happen automatically merely by marking the type collatable.

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Array Types

Whenever a user-defined type is created, WarehousePG automatically creates an associated array type, whose name consists of the element type's name prepended with an underscore, and truncated if necessary to keep it less than `NAMEDATALEN` bytes long. (If the name so generated collides with an existing type name, the process is repeated until a non-colliding name is found.) This implicitly-created array type is variable length and uses the built-in input and output functions `array_in` and `array_out`. The array type tracks any changes in its element type's owner or schema, and is dropped if the element type is.

Why is there is an `ELEMENT` option, when the system makes the correct array type automatically? The only case where it's useful to use `ELEMENT` is when you are making a fixed-length type that happens to be internally an array of a number of identical things, and you want to allow these things to be accessed directly by subscripting, in addition to whatever operations you plan to provide for the type as a whole. For example, type `point` is represented as just two floating-point numbers, each can be accessed using `point[0]` and `point[1]`. Note that this facility only works for fixed-length types whose internal form is exactly a sequence of identical fixed-length fields. A subscriptable variable-length type must have the generalized internal representation used by `array_in` and `array_out`. For historical reasons, subscripting of fixed-length array types starts from zero, rather than from one as for variable-length arrays.

Parameters

name The name (optionally schema-qualified) of a type to be created.

attribute_name The name of an attribute (column) for the composite type.

data_type The name of an existing data type to become a column of the composite type.

collation The name of an existing collation to be associated with a column of a composite type, or with a range type.

label A string literal representing the textual label associated with one value of an enum type.

subtype The name of the element type that the range type will represent ranges of.

subtype_operator_class The name of a b-tree operator class for the subtype.

canonical_function The name of the canonicalization function for the range type.

subtype_diff_function The name of a difference function for the subtype.

input_function The name of a function that converts data from the type's external textual form to its internal form.

output_function The name of a function that converts data from the type's internal form to its external textual form.

receive_function The name of a function that converts data from the type's external binary form to its internal form.

send_function The name of a function that converts data from the type's internal form to its external binary form.

type_modifier_input_function The name of a function that converts an array of modifier(s) for the type to internal form.

type_modifier_output_function The name of a function that converts the internal form of the type's modifier(s) to external textual form.

analyze_function The name of a function that performs statistical analysis for the data type.

internallength A numeric constant that specifies the length in bytes of the new type's internal representation. The default assumption is that it is variable-length.

alignment The storage alignment requirement of the data type. Must be one of `char`, `int2`, `int4`, or `double`. The default is `int4`.

storage The storage strategy for the data type. Must be one of `plain`, `external`, `extended`, or `main`. The default is `plain`.

like_type The name of an existing data type that the new type will have the same representation as. The values internallength, passedbyvalue, alignment, and storage, are copied from that type, unless overridden by explicit specification elsewhere in this `CREATE TYPE` command.

category The category code (a single ASCII character) for this type. The default is '`U`', signifying a user-defined type. You can find the other standard category codes in `pg_type` Category Codes. You may also assign unused ASCII characters to custom categories that you create.

preferred `true` if this type is a preferred type within its type category, else `false`. The default value is `false`. Be careful when you create a new preferred type within an existing type category; this could cause surprising behaviour changes.

default The default value for the data type. If this is omitted, the default is null.

element The type being created is an array; this specifies the type of the array elements.

delimiter The delimiter character to be used between values in arrays made of this type.

collatable True if this type's operations can use collation information. The default is false.

compression_type Set to `ZLIB` (the default), `ZSTD`, or `RLE_TYPE` to specify the type of compression used in columns of this type.

compression_level For Zstd compression, set to an integer value from 1 (fastest compression) to 19 (highest compression ratio). For zlib compression, the valid range is from 1 to 9. For `RLE_TYPE`, the compression level can be set to an integer value from 1 (fastest compression) to 6 (highest compression ratio). The default compression level is 1.

blocksize Set to the size, in bytes, for each block in the column. The `BLOCKSIZE` must be between 8192 and 2097152 bytes, and be a multiple of 8192. The default block size is 32768.

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Notes

User-defined type names cannot begin with the underscore character (_) and can only be 62 characters long (or in general `NAMEDATALEN - 2`, rather than the `NAMEDATALEN - 1` characters allowed for other names). Type names beginning with underscore are reserved for internally-created array type names.

WarehousePG does not support adding storage options for row or composite types.

Storage options defined at the table- and column- level override the default storage options defined for a scalar type.

Because there are no restrictions on use of a data type once it's been created, creating a base type or range type is tantamount to granting public execute permission on the functions mentioned in the type definition. (The creator of the type is therefore required to own these functions.) This is usually not an issue for the sorts of functions that are useful in a type definition. But you might want to think twice before designing a type in a way that would require 'secret' information to be used while converting it to or from external form.

Use `pg_type.typarray` to locate the array type associated with a given type.

Examples

This example creates a composite type and uses it in a function definition:

```
CREATE TYPE compfoo AS (f1 int, f2 text);

CREATE FUNCTION getfoo() RETURNS SETOF compfoo AS $$
    SELECT fooid, fooname FROM foo
$$ LANGUAGE SQL;
```

This example creates the enumerated type `mood` and uses it in a table definition.

```
CREATE TYPE mood AS ENUM ('sad', 'ok', 'happy');
CREATE TABLE person (
    name text,
    current_mood mood
);
INSERT INTO person VALUES ('Moe', 'happy');
SELECT * FROM person WHERE current_mood = 'happy';
 name | current_mood
------+--------------
 Moe  | happy
(1 row)
```

This example creates a range type:

```
CREATE TYPE float8_range AS RANGE (subtype = float8, subtype_diff = float8mi);
```

This example creates the base data type `box` and then uses the type in a table definition:

```
CREATE TYPE box;

CREATE FUNCTION my_box_in_function(cstring) RETURNS box AS
... ;

CREATE FUNCTION my_box_out_function(box) RETURNS cstring AS
... ;

CREATE TYPE box (
    INTERNALLENGTH = 16,
    INPUT = my_box_in_function,
    OUTPUT = my_box_out_function
);

CREATE TABLE myboxes (
    id integer,
    description box
);
```

If the internal structure of `box` were an array of four `float4` elements, we might instead use:

```
CREATE TYPE box (
    INTERNALLENGTH = 16,
    INPUT = my_box_in_function,
    OUTPUT = my_box_out_function,
    ELEMENT = float4
);
```

which would allow a box value's component numbers to be accessed by subscripting. Otherwise the type behaves the same as before.

This example creates a large object type and uses it in a table definition:

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```
CREATE TYPE bigobj (
    INPUT = lo_filein, OUTPUT = lo_fileout,
    INTERNALLENGTH = VARIABLE
);

CREATE TABLE big_objs (
    id integer,
    obj bigobj
    );
```

Compatibility

The first form of the `CREATE TYPE` command, which creates a composite type, conforms to the SQL standard. The other forms are WarehousePG extensions. The `CREATE TYPE` statement in the SQL standard also defines other forms that are not implemented in WarehousePG.

The ability to create a composite type with zero attributes is a WarehousePG-specific deviation from the standard (analogous to the same case in `CREATE TABLE`).

See Also

ALTER TYPE, CREATE DOMAIN, CREATE FUNCTION, DROP TYPE

Parent topic: SQL Commands

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7.1.89 CREATE USER

Defines a new database role.

Synopsis

```
CREATE USER <name> [[WITH] <option> [ ... ]]

where option can be:
      SUPERUSER | NOSUPERUSER
    | CREATEDB | NOCREATEDB
    | CREATEROLE | NOCREATEROLE
    | CREATEEXTTABLE | NOCREATEEXTTABLE
      [ ( <attribute>='<value>'[, ...] ) ]
           where <attributes> and <value> are:
           type='readable'|'writable'
           protocol='gpfdist'|'http'
    | INHERIT | NOINHERIT
    | LOGIN | NOLOGIN
    | REPLICATION | NOREPLICATION
    | BYPASSRLS | NOBYPASSRLS
    | CONNECTION LIMIT <connlimit>
    | [ ENCRYPTED ] PASSWORD '<password>' | PASSWORD NULL
    | VALID UNTIL '<timestamp>'
    | IN ROLE <role_name> [, ...]
    | IN GROUP <role_name>
    | ROLE <role_name> [, ...]
    | ADMIN <role_name> [, ...]
    | USER <role_name> [, ...]
    | SYSID <uid>
    | RESOURCE QUEUE <queue_name>
    | RESOURCE GROUP <group_name>
    | [ DENY <deny_point> ]
    | [ DENY BETWEEN <deny_point> AND <deny_point>]
```

Description

`CREATE USER` is an alias for CREATE ROLE. The only difference is that when the command `CREATE USER` is invoked, `LOGIN` is assumed by default, whereas `NOLOGIN` is assumed when the command invoked is `CREATE ROLE`.

Compatibility

The `CREATE USER` statement is a WarehousePG extension. The SQL standard leaves the definition of users to the implementation.

See Also

CREATE ROLE

Parent topic: SQL Commands

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7.1.90 CREATE USER MAPPING

Defines a new mapping of a user to a foreign server.

Synopsis

```
CREATE USER MAPPING [ IF NOT EXISTS ] FOR { <user_name> | USER | CURRENT_USER | PUBLIC }
    SERVER <server_name>
    [ OPTIONS ( <option> '<value>' [, ... ] ) ]
```

Description

`CREATE USER MAPPING` defines a mapping of a user to a foreign server. A user mapping typically encapsulates connection information that a foreign-data wrapper uses together with the information encapsulated by a foreign server to access an external data resource.

The owner of a foreign server can create user mappings for that server for any user. Also, a user can create a user mapping for their own user name if they have been granted `USAGE` privilege on the server.

Parameters

IF NOT EXISTS Do not throw an error if a mapping of the given user to the given foreign server already exists. WarehousePG issues a notice in this case. Note that there is no guarantee that the existing user mapping is anything like the one that would have been created.

user_name The name of an existing user that is mapped to the foreign server. `CURRENT_USER` and `USER` match the name of the current user. When `PUBLIC` is specified, WarehousePG creates a so-called public mapping that is used when no user-specific mapping is applicable.

server_name The name of an existing server for which WarehousePG is to create the user mapping.

OPTIONS (option 'value' [, ...]) The options for the new user mapping. The options typically define the actual user name and password of the mapping. Option names must be unique. The option names and values are specific to the server's foreign-data wrapper.

Examples

Create a user mapping for user `bob`, server `foo`:

```
CREATE USER MAPPING FOR bob SERVER foo OPTIONS (user 'bob', password 'secret');
```

Compatibility

`CREATE USER MAPPING` conforms to ISO/IEC 9075-9 (SQL/MED).

See Also

ALTER USER MAPPING, DROP USER MAPPING, CREATE FOREIGN DATA WRAPPER, CREATE SERVER

Parent topic: SQL Commands

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7.1.91 CREATE VIEW

Defines a new view.

Synopsis

```
CREATE [OR REPLACE] [TEMP | TEMPORARY] [RECURSIVE] VIEW <name> [ ( <column_name> [, ...] ) ]
    [ WITH ( view_option_name [= view_option_value] [, ... ] ) ]
    AS <query>
    [ WITH [ CASCADED | LOCAL ] CHECK OPTION ]
```

Description

`CREATE VIEW` defines a view of a query. The view is not physically materialized. Instead, WarehousePG runs the query every time the view is referenced in a query.

`CREATE OR REPLACE VIEW` is similar, but if a view of the same name already exists, it is replaced. The new query must generate the same columns that were generated by the existing view query (that is, the same column names in the same order, and with the same data types), but it may add additional columns to the end of the list. The calculations giving rise to the output columns may be completely different.

If a schema name is given (for example, `CREATE VIEW myschema.myview ...`) then the view is created in the specified schema. Otherwise it is created in the current schema. Temporary views exist in a special schema, so you may not provide a schema name when creating a temporary view. The name of the view must be distinct from the name of any other view, table, sequence, index, or foreign table in the same schema.

Parameters

TEMPORARY | TEMP If specified, the view is created as a temporary view. Temporary views are automatically dropped at the end of the current session. Existing permanent relations with the same name are not visible to the current session while the temporary view exists, unless they are referenced with schema-qualified names. If any of the tables referenced by the view are temporary, the view is created as a temporary view (whether `TEMPORARY` is specified or not).

RECURSIVE Creates a recursive view. The syntax

```
```
CREATE RECURSIVE VIEW [<schema> .] <view_name> (<column_names>) AS SELECT <...>;
```

is equivalent to

```
```
CREATE VIEW [ <schema> . ] <view_name> AS WITH RECURSIVE <view_name> (<column_names>) AS (SELECT <...>) SELECT <column_names> FROM <view_name>;
```

A view column name list must be specified for a recursive view.
```

name The name (optionally schema-qualified) of a view to be created.

column_name An optional list of names to be used for columns of the view. If not given, the column names are deduced from the query.

WITH ( view_option_name [= view_option_value] [, ... ] ) This clause specifies optional parameters for a view; the following parameters are supported:

```
check_option \(string\)
This parameter may be either `local` or `cascaded`, and is equivalent to specifying `WITH [ CASCADED | LOCAL ] CHECK OPTION` \(see below\). This option can be
changed on existing views using [ALTER VIEW](ALTER_VIEW.html).

security_barrier \(boolean\)
This should be used if the view is intended to provide row-level security. Refer to [Rules and Privileges](https://www.postgresql.org/docs/12/rules-
privileges.html) in the PostgreSQL documentation for more information.
```

query A SELECT or VALUES command which will provide the columns and rows of the view.

WITH [CASCADED | LOCAL] CHECK OPTION This option controls the behavior of automatically updatable views. When this option is specified, `INSERT` and `UPDATE` commands on the view will be checked to ensure that new rows satisfy the view-defining condition (that is, the new rows are checked to ensure that they are visible through the view). If they are not, WarehousePG Databvase rejects the update. If the `CHECK OPTION` is not specified, `INSERT` and `UPDATE` commands on the view are allowed to create rows that are not visible through the view. The following check options are supported:

```
LOCAL
New rows are only checked against the conditions defined directly in the view itself. Any conditions defined on underlying base views are not checked \(unless
they also specify the `CHECK OPTION`\).

CASCADED
New rows are checked against the conditions of the view and all underlying base views. If the `CHECK OPTION` is specified, and neither `LOCAL` nor `CASCADED` is
specified, then `CASCADED` is assumed.
```

The `CHECK OPTION` may not be used with `RECURSIVE` views.

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```

Notes

Use the DROP VIEW statement to drop views.

Ensure that the names and data types of the view's columns are assigned the way you want. For example:

```
CREATE VIEW vista AS SELECT 'Hello World';
```

is bad form in two ways: the column name defaults to `?column?`, and the column data type defaults to `text`, which might not be what you wanted. If you want a string literal in a view's result, use something like:

```
CREATE VIEW vista AS SELECT text 'Hello World' AS hello;
```

Access to tables referenced in the view is determined by permissions of the view owner not the current user (even if the current user is a superuser). This can be confusing in the case of superusers, since superusers typically have access to all objects. In the case of a view, even superusers must be explicitly granted access to tables referenced in the view if they are not the owner of the view. In some cases, a view can be used to provide secure but restricted access to the underlying tables. However, not all views are secure against tampering, see Rules and Privileges in the PostgreSQL documentation for details.

Functions called in the view are treated the same as if they had been called directly from the query using the view. Therefore the user of a view must have permissions to call any functions used by the view.

When both `CREATE VIEW <view> ...` and `SELECT ... FROM <view>` specify an `ORDER BY` clause, WarehousePG ignores the `ORDER BY` clause in the `CREATE VIEW` statement.

When `CREATE OR REPLACE VIEW` is used on an existing view, only the view's defining `SELECT` rule is changed. Other view properties, including ownership, permissions, and non-`SELECT` rules, remain unchanged. You must own the view to replace it (this includes being a member of the owning role).

Updatable Views

Simple views are automatically updatable: WarehousePG allows you to invoke `INSERT`, `UPDATE`, and `DELETE` statements on the view in the same way as on a regular table. A view is automatically updatable if it satisfies all of the following conditions:

- The view must have exactly one entry in its `FROM` list, which must be a table or another updatable view.
- The view definition must not contain `WITH`, `DISTINCT`, `GROUP BY`, `HAVING`, `LIMIT`, or `OFFSET` clauses at the top level.
- The view definition must not contain set operations (`UNION`, `INTERSECT`, or `EXCEPT`) at the top level.
- The view's select list must not contain any aggregates, window functions, or set-returning functions.

An automatically updatable view may contain a mix of updatable and non-updatable columns. A column is updatable if it is a simple reference to an updatable column of the underlying base relation; otherwise the column is read-only, and WarehousePG raises an error if an `INSERT` or `UPDATE` statement attempts to assign a value to it.

If the view is automatically updatable the system will convert any `INSERT`, `UPDATE`, or `DELETE` statement on the view into the corresponding statement on the underlying base relation. `INSERT` statements that have an `ON CONFLICT UPDATE` clause are fully supported.

If an automatically updatable view contains a `WHERE` condition, the condition restricts which rows of the base relation are available to be modified by `UPDATE` and `DELETE` statements on the view. However, an `UPDATE` is permitted to change a row so that it no longer satisfies the `WHERE` condition, and thus is no longer visible through the view. Similarly, an `INSERT` command can potentially insert base-relation rows that do not satisfy the `WHERE` condition and thus are not visible through the view (`ON CONFLICT UPDATE` may similarly affect an existing row not visible through the view). The `CHECK OPTION` may be used to prevent `INSERT` and `UPDATE` commands from creating such rows that are not visible through the view.

If an automatically updatable view is marked with the `security_barrier` property, then all of the view's `WHERE` conditions (and any conditions using operators which are marked as `LEAKPROOF`) will always be evaluated before any conditions that a user of the view has added. Refer to Rules and Privileges in the PostgreSQL documenatation for full details. Note that, due to this, rows which are not ultimately returned (because they do not pass the user's `WHERE` conditions) may still end up being locked. You can use the `EXPLAIN` command to see which conditions are applied at the relation level (and therefore do not lock rows) and which are not.

A more complex view that does not satisfy all of these conditions is read-only by default: the system will not allow an insert, update, or delete on the view. You can get the effect of an updatable view by creating rules (see CREATE RULE).

Note that the user performing the insert, update or delete on the view must have the corresponding insert, update or delete privilege on the view. In addition the view's owner must have the relevant privileges on the underlying base relations, but the user performing the update does not need any permissions on the underlying base relations (again, refer to Rules and Privileges in the PostgreSQL documentation).

Examples

Create a view consisting of all comedy films:

```
CREATE VIEW comedies AS
    SELECT * FROM films
    WHERE kind = 'comedy';
```

This creates a view containing the columns that are in the `film` table at the time of view creation. Though `*` was used to create the view, columns added later to the table will not be part of the view.

Create a view with `LOCAL CHECK OPTION`:

```
CREATE VIEW universal_comedies AS
    SELECT *
    FROM comedies
    WHERE classification = 'U'
    WITH LOCAL CHECK OPTION;
```

This creates a view based on the comedies `view`, showing only films with `kind = 'Comedy'` and `classification = 'U'`. Any attempt to `INSERT` or `UPDATE` a row in the view is rejected if the new row doesn't have `classification = 'U'`, but the film `kind` will not be checked.

Create a view with `CASCADED CHECK OPTION`:

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```
CREATE VIEW pg_comedies AS
    SELECT *
    FROM comedies
    WHERE classification = 'PG'
    WITH CASCADED CHECK OPTION;
```

This creates a view that checks both the `kind` and `classification` of new rows.

Create a view with a mix of updatable and non-updatable columns:

```
CREATE VIEW comedies AS
    SELECT f.*,
           country_code_to_name(f.country_code) AS country,
           (SELECT avg(r.rating)
            FROM user_ratings r
            WHERE r.film_id = f.id) AS avg_rating
    FROM films f
    WHERE f.kind = 'Comedy';
```

This view supports `INSERT`, `UPDATE`, and `DELETE`. All the columns from the `films` table will be updatable, whereas the computed columns `country` and `avg_rating` will be read-only.

Create a view that gets the top ten ranked baby names:

```
CREATE VIEW topten AS
    SELECT name, rank, gender, year
    FROM names, rank
    WHERE rank < '11' AND names.id=rank.id;
```

Create a recursive view consisting of the numbers from 1 to 100:

```
CREATE RECURSIVE VIEW public.nums_1_100 (n) AS
    VALUES (1)
UNION ALL
    SELECT n+1 FROM nums_1_100 WHERE n < 100;
```

Notice that although the recursive view's name is schema-qualified in this `CREATE VIEW` command, its internal self-reference is not schema-qualified. This is because the implicitly-created CTE's name cannot be schema-qualified.

Compatibility

`CREATE OR REPLACE VIEW` is a WarehousePG extension. So is the concept of a temporary view. The `WITH ( ... )` clause is an extension as well.

See Also

ALTER VIEW, DROP VIEW, CREATE MATERIALIZED VIEW

Parent topic: SQL Commands

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7.1.92 DEALLOCATE

Deallocates a prepared statement.

Synopsis

```
DEALLOCATE [PREPARE] { <name> | ALL }
```

Description

`DEALLOCATE` is used to deallocate a previously prepared SQL statement. If you do not explicitly deallocate a prepared statement, it is deallocated when the session ends.

For more information on prepared statements, see PREPARE.

Parameters

PREPARE Optional key word which is ignored.

name The name of the prepared statement to deallocate.

ALL Deallocate all prepared statements

Examples

Deallocate the previously prepared statement named `insert_names`:

```
DEALLOCATE insert_names;
```

Compatibility

The SQL standard includes a `DEALLOCATE` statement, but it is only for use in embedded SQL.

See Also

EXECUTE, PREPARE

Parent topic: SQL Commands

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7.1.93 DECLARE

Defines a cursor.

Synopsis

```
DECLARE <name> [BINARY] [INSENSITIVE] [NO SCROLL] [PARALLEL RETRIEVE] CURSOR
     [{WITH | WITHOUT} HOLD]
     FOR <query>
```

Description

`DECLARE` allows a user to create a cursor, which can be used to retrieve a small number of rows at a time out of a larger query. Cursors can return data using`FETCH`.

> **Note** This page describes usage of cursors at the SQL command level. If you are trying to use cursors inside a PL/pgSQL function, the rules are different, see`PL/pgSQL`.

Normal cursors return data in text format, the same as a `SELECT` would produce. Since data is stored natively in binary format, the system must do a conversion to produce the text format. Once the information comes back in text form, the client application may need to convert it to a binary format to manipulate it. In addition, data in the text format is often larger in size than in the binary format. Binary cursors return the data in a binary representation that may be more easily manipulated. Nevertheless, if you intend to display the data as text anyway, retrieving it in text form will save you some effort on the client side.

As an example, if a query returns a value of one from an integer column, you would get a string of 1 with a default cursor whereas with a binary cursor you would get a 4-byte field containing the internal representation of the value (in big-endian byte order).

Binary cursors should be used carefully. Many applications, including `psql`, are not prepared to handle binary cursors and expect data to come back in the text format.

> **Note** When the client application uses the 'extended query' protocol to issue a `FETCH` command, the Bind protocol message specifies whether data is to be retrieved in text or binary format. This choice overrides the way that the cursor is defined. The concept of a binary cursor as such is thus obsolete when using extended query protocol — any cursor can be treated as either text or binary.

A cursor can be specified in the `WHERE CURRENT OF` clause of the`UPDATE` or`DELETE` statement to update or delete table data. The `UPDATE` or `DELETE` statement can only be run on the server, for example in an interactive `psql` session or a script.

Parallel Retrieve Cursors

WarehousePG supports a special type of cursor, a *parallel retrieve cursor*. You can use a parallel retrieve cursor to retrieve query results, in parallel, directly from the WarehousePG segments, bypassing the WarehousePG coordinator.

Parallel retrieve cursors do not support the `WITH HOLD` clause. WarehousePG ignores the `BINARY` clause when you declare a parallel retrieve cursor.

You open a special retrieve session to each parallel retrieve cursor endpoint, and use the`RETRIEVE` command to retrieve the query results from a parallel retrieve cursor.

Parameters

name The name of the cursor to be created.

BINARY Causes the cursor to return data in binary rather than in text format.

```
> **Note** WarehousePG ignores the `BINARY` clause when you declare a `PARALLEL RETRIEVE` cursor.
```

INSENSITIVE Indicates that data retrieved from the cursor should be unaffected by updates to the table(s) underlying the cursor that occur after the cursor is created. In WarehousePG, all cursors are insensitive. This key word currently has no effect and is present only for compatibility with the SQL standard.

NO SCROLL The cursor cannot be used to retrieve rows in a nonsequential fashion. This is the default behavior in WarehousePG; scrollable cursors `SCROLL`) are not supported.

PARALLEL RETRIEVE Declare a parallel retrieve cursor. A parallel retrieve cursor is a special type of cursor that you can use to retrieve results directly from WarehousePG segments, in parallel.

WITH HOLD WITHOUT HOLD `WITH HOLD` specifies that the cursor may continue to be used after the transaction that created it successfully commits. `WITHOUT HOLD` specifies that the cursor cannot be used outside of the transaction that created it. `WITHOUT HOLD` is the default.

```
> **Note** WarehousePG does not support declaring a `PARALLEL RETRIEVE` cursor with the `WITH HOLD` clause. `WITH HOLD` also cannot not be specified when the
`query` includes a `FOR UPDATE` or `FOR SHARE` clause.
```

query A`SELECT` or`VALUES` command which will provide the rows to be returned by the cursor.

If the cursor is used in the `WHERE CURRENT OF` clause of the`UPDATE` or`DELETE` command, the `SELECT` command must satisfy the following conditions:

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```
-   Cannot reference a view or external table.
-   References only one table.
    <br/><br/>The table must be a heap table, and it must not be replicated-distributed (must not be a view, external table, or append-optimized column-oriented
table).

-   Cannot contain any of the following:
    -   A grouping clause
    -   A set operation such as `UNION ALL` or `UNION DISTINCT`
    -   A sorting clause
    -   A windowing clause
    -   A join or a self-join
    <br/><br/>Specifying the `FOR UPDATE` clause in the `SELECT` command prevents other sessions from changing the rows between the time they are fetched and the
time they are updated. Without the `FOR UPDATE` clause, a subsequent use of the `UPDATE` or `DELETE` command with the `WHERE CURRENT OF` clause has no effect if
the row was changed since the cursor was created.
    <br/><br/>> **Note** Specifying the `FOR UPDATE` clause in the `SELECT` command locks the entire table, not just the selected rows.
```

The key words `BINARY`, `INSENSITIVE`, and `NO SCROLL` can appear in any order.

Notes

Unless `WITH HOLD` is specified, the cursor created by this command can only be used within the current transaction. Thus, `DECLARE` without `WITH HOLD` is useless outside a transaction block: the cursor would survive only to the completion of the statement. Therefore WarehousePG reports an error if this command is used outside a transaction block. Use `BEGIN` and `COMMIT` (or `ROLLBACK`) to define a transaction block.

If `WITH HOLD` is specified and the transaction that created the cursor successfully commits, the cursor can continue to be accessed by subsequent transactions in the same session. (But if the creating transaction ends prematurely, the cursor is removed.) A cursor created with `WITH HOLD` is closed when an explicit `CLOSE` command is issued on it, or the session ends. In the current implementation, the rows represented by a held cursor are copied into a temporary file or memory area so that they remain available for subsequent transactions.

If you create a cursor with the `DECLARE` command in a transaction, you cannot use the `SET` command in the transaction until you close the cursor with the `CLOSE` command.

Scrollable cursors are not currently supported in WarehousePG. You can only use `FETCH` or `RETRIEVE` to move the cursor position forward, not backwards.

`DECLARE...FOR UPDATE` is not supported with append-optimized tables.

You can see all available cursors by querying the pg_cursors system view.

Examples

Declare a cursor:

```
DECLARE mycursor CURSOR FOR SELECT * FROM mytable;
```

Declare a parallel retrieve cursor for the same query:

```
DECLARE myprcursor PARALLEL RETRIEVE CURSOR FOR SELECT * FROM mytable;
```

Compatibility

SQL standard allows cursors only in embedded SQL and in modules. WarehousePG permits cursors to be used interactively.

WarehousePG does not implement an `OPEN` statement for cursors. A cursor is considered to be open when it is declared.

The SQL standard allows cursors to move both forward and backward. All WarehousePG cursors are forward moving only (not scrollable).

Binary cursors are a WarehousePG extension.

The SQL standard makes no provisions for parallel retrieve cursors.

See Also

CLOSE, DELETE, FETCH, MOVE, RETRIEVE, SELECT, UPDATE

Parent topic: SQL Commands

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7.1.94 DELETE

Deletes rows from a table.

Synopsis

```
[ WITH [ RECURSIVE ] <with_query> [, ...] ]
DELETE FROM [ONLY] <table_name> [[AS] <alias>]
      [USING <from_item> [, ...] ]
      [WHERE <condition> | WHERE CURRENT OF <cursor_name>]
      [RETURNING * | <output_expression> [[AS] <output_name>] [, …]]
```

Description

`DELETE` deletes rows that satisfy the `WHERE` clause from the specified table. If the `WHERE` clause is absent, the effect is to delete all rows in the table. The result is a valid, but empty table.

Tip: TRUNCATE provides a faster mechanism to remove all rows from a table.

There are two ways to delete rows in a table using information contained in other tables in the database: using sub-selects, or specifying additional tables in the `USING` clause. Which technique is more appropriate depends on the specific circumstances.

The optional `RETURNING` clause causes `DELETE` to compute and return value(s) based on each row actually deleted. Any expression using the table's columns, and/or columns of other tables mentioned in `USING`, can be computed. The syntax of the `RETURNING` list is identical to that of the output list of `SELECT`.

You must have the `DELETE` privilege on the table to delete from it, as well as the `SELECT` privilege for any table in the `USING` clause or whose values are read in the condition.

> **Note** The `RETURNING` clause is not supported when deleting from append-optimized tables.

> **Note** As the default, WarehousePG acquires an `EXCLUSIVE` lock on tables for `DELETE` operations on heap tables. When the Global Deadlock Detector is enabled, the lock mode for `DELETE` operations on heap tables is `ROW EXCLUSIVE`. See Global Deadlock Detector.

Parameters

with_query The `WITH` clause allows you to specify one or more subqueries that can be referenced by name in the `DELETE` query.

For a `DELETE` command that includes a `WITH` clause, the clause can only contain `SELECT` statements, the `WITH` clause cannot contain a data-modifying command (`INSERT`, `UPDATE`, or `DELETE`).

See WITH Queries (Common Table Expressions) and SELECT for details.

table_name The name (optionally schema-qualified) of the table to delete rows from. If you specify `ONLY` before the table name, WarehousePG deletes matching rows from the named table only. If `ONLY` is not specified, matching rows are also deleted from any tables inheriting from the named table. Optionally, you can specify `*` after the table name to explicitly indicate that descendant tables are included.

alias A substitute name for the target table. When an alias is provided, it completely hides the actual name of the table. For example, given `DELETE FROM foo AS f`, the remainder of the `DELETE` statement must refer to this table as `f` not `foo`.

from_item A table expression allowing columns from other tables to appear in the `WHERE` condition. This uses the same syntax as the `FROM` clause of a SELECT statement; for example, you can specify an alias for the table name. Do not repeat the target table in the from_item, unless you wish to set up a self-join (in which case it must appear with an alias in the from_item).

condition An expression that returns a value of type `boolean`. WarehousePG deletes only those rows for which this expression returns `true`.

cursor_name The name of the cursor to use in a `WHERE CURRENT OF` condition. The row to be deleted is the one most recently fetched from this cursor. The cursor must be a non-grouping query on the `DELETE`'s target table. Note that `WHERE CURRENT OF` cannot be specified together with a Boolean condition. See DECLARE for more information about using cursors with `WHERE CURRENT OF`.

The `DELETE...WHERE CURRENT OF` cursor statement can only be run on the server, for example in an interactive psql session or a script. Language extensions such as PL/pgSQL do not have support for updatable cursors.

output_expression An expression to be computed and returned by the `DELETE` command after each row is deleted. The expression can use any column names of the table named by table_name or table(s) listed in `USING`. Write `*` to return all columns.

output_name A name to use for a returned column.

Outputs

On successful completion, a `DELETE` command returns a command tag of the form

```
DELETE <count>
```

The count is the number of rows deleted. If count is 0, no rows were deleted by the query (this is not considered an error).

If the `DELETE` command contains a `RETURNING` clause, the result will be similar to that of a `SELECT` statement containing the columns and values defined in the `RETURNING` list, computed over the row(s) deleted by the command.

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Notes

The `RETURNING` clause is not supported when deleting from append-optimized tables.

The `WHERE CURRENT OF` clause is not supported with replicated tables.

WarehousePG lets you reference columns of other tables in the `WHERE` condition by specifying the other tables in the `USING` clause. For example, to delete all films produced by a given producer, one can run:

```
DELETE FROM films USING producers
  WHERE producer_id = producers.id AND producers.name = 'foo';
```

What is essentially happening here is a join between `films` and `producers`, with all successfully joined `films` rows being marked for deletion. This syntax is not standard. A more standard way to accomplish this is:

```
DELETE FROM films
  WHERE producer_id IN (SELECT id FROM producers WHERE name = 'foo');
```

For a partitioned table, all of the child tables are locked during the `DELETE` operation when the Global Deadlock Detector is not enabled (the default). Only some of the leaf child tables are locked when the Global Deadlock Detector is enabled. For information about the Global Deadlock Detector, see Global Deadlock Detector.

Examples

Delete all films but musicals:

```
DELETE FROM films WHERE kind <> 'Musical';
```

Clear the table films:

```
DELETE FROM films;
```

Delete completed tasks, returning full details of the deleted rows:

```
DELETE FROM tasks WHERE status = 'DONE' RETURNING *;
```

Delete the row of tasks on which the cursor `c_tasks` is currently positioned:

```
DELETE FROM tasks WHERE CURRENT OF c_tasks;
```

Delete using a join:

```
DELETE FROM rank USING names WHERE names.id = rank.id AND
name = 'Hannah';
```

Compatibility

This command conforms to the SQL standard, except that the `USING` and `RETURNING` clauses are WarehousePG extensions, as is the ability to use `WITH` with `DELETE`.

See Also

TRUNCATE

Parent topic: SQL Commands

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7.1.95 DISCARD

Discards the session state.

Synopsis

```
DISCARD { ALL | PLANS | SEQUENCES | TEMPORARY | TEMP }
```

Description

`DISCARD` releases internal resources associated with a database session. This command is useful for partially or fully resetting the session's state. There are several subcommands to release different types of resources; the `DISCARD ALL` variant subsumes all the others, and also resets additional state.

WarehousePG does not support invoking `DISCARD ALL` in a transaction.

Parameters

PLANS Releases all cached query plans, forcing re-planning to occur the next time the associated prepared statement is used.

SEQUENCES Discards all cached sequence-related state, including any preallocated sequence values that have not yet been returned by `nextval()`. (See CREATE SEQUENCE for a description of preallocated sequence values.)

TEMPORARY/TEMP Drops all temporary tables created in the current session.

ALL Releases all temporary resources associated with the current session and resets the session to its initial state. Currently, this has the same effect as executing the following sequence of statements:

```
```
CLOSE ALL;
SET SESSION AUTHORIZATION DEFAULT;
RESET ALL;
DEALLOCATE ALL;
UNLISTEN *;
SELECT pg_advisory_unlock_all();
DISCARD PLANS;
DISCARD SEQUENCES;
DISCARD TEMP;
```
```

Notes

`DISCARD ALL` cannot be run inside a transaction block.

Compatibility

`DISCARD` is a WarehousePG extension.

Parent topic: SQL Commands

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7.1.96 DO

Runs anonymous code block as a transient anonymous function.

Synopsis

```
DO [ LANGUAGE <lang_name> ] <code>
```

Description

`DO` runs an anonymous code block, or in other words a transient anonymous function in a procedural language.

The code block is treated as though it were the body of a function with no parameters, returning `void`. It is parsed and run a single time.

The optional `LANGUAGE` clause can appear either before or after the code block.

Anonymous blocks are procedural language structures that provide the capability to create and run procedural code on the fly without persistently storing the code as database objects in the system catalogs. The concept of anonymous blocks is similar to UNIX shell scripts, which enable several manually entered commands to be grouped and run as one step. As the name implies, anonymous blocks do not have a name, and for this reason they cannot be referenced from other objects. Although built dynamically, anonymous blocks can be easily stored as scripts in the operating system files for repetitive execution.

Anonymous blocks are standard procedural language blocks. They carry the syntax and obey the rules that apply to the procedural language, including declaration and scope of variables, execution, exception handling, and language usage.

The compilation and execution of anonymous blocks are combined in one step, while a user-defined function needs to be re-defined before use each time its definition changes.

Parameters

code The procedural language code to be run. This must be specified as a string literal, just as with the `CREATE FUNCTION` command. Use of a dollar-quoted literal is recommended.

lang_name The name of the procedural language in which the code is written. The default is `plpgsql`.

Notes

The procedural language to be used must already have been installed into the current database by means of `CREATE EXTENSION`. The PL/pgSQL language is installed wih WarehousePG and is registered by default every user-created database. The PL/Python and PL/Perl languages are installed by default, but not registered. Other languages are neither installed nor registered. The pg_language system catalog contains information about the registered languages in a database.

The user must have `USAGE` privilege for the procedural language, or must be a superuser if the language is untrusted. This is the same privilege requirement as for creating a function in the language.

If `DO` is run in a transaction block, then the procedure code cannot execute transaction control statements. Transaction control statements are allowed only if `DO` is run in its own transaction.

Anonymous blocks do not support function volatility or `EXECUTE ON` attributes.

Examples

This PL/pgSQL example grants all privileges on all views in schema `public` to role `webuser`:

```
DO $$DECLARE r record;
BEGIN
    FOR r IN SELECT table_schema, table_name FROM information_schema.tables
             WHERE table_type = 'VIEW' AND table_schema = 'public'
    LOOP
        EXECUTE 'GRANT ALL ON ' || quote_ident(r.table_schema) || '.' || quote_ident(r.table_name) || ' TO webuser';
    END LOOP;
END$$;
```

Compatibility

There is no `DO` statement in the SQL standard.

See Also

CREATE LANGUAGE

Parent topic: SQL Commands

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7.1.97 DROP ACCESS METHOD

Removes an access method

Synopsis

```
DROP ACCESS METHOD [IF EXISTS] <name> [CASCADE | RESTRICT]
```

Description

`DROP ACCESS METHOD` removes an existing access method. Only superusers can drop access methods.

Parameters

IF EXISTS Do not throw an error if the access method does not exist. WarehousePG issues a notice in this case.

name The name of an existing access method.

CASCADE Automatically drop objects that depend on the access method (such as operator classes, operator families, and indexes), and in turn all objects that depend on those objects.

RESTRICT Refuse to drop the access method if any objects depend on it. This is the default.

Examples

Drop the access method `heptree`;

```
DROP ACCESS METHOD
heptree;
```

Compatibility

`DROP ACCESS METHOD` is a WarehousePG extension.

See Also

CREATE ACCESS METHOD

Parent topic: SQL Commands

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7.1.98 DROP AGGREGATE

Removes an aggregate function.

Synopsis

```
DROP AGGREGATE [IF EXISTS] <name> ( <aggregate_signature> ) [, ...] [CASCADE | RESTRICT]

where <aggregate_signature> is:

* |
[ <argmode> ] [ <argname> ] <argtype> [ , ... ] |
[ [ <argmode> ] [ <argname> ] <argtype> [ , ... ] ] ORDER BY [ <argmode> ] [ <argname> ] <argtype> [ , ... ]
```

Description

`DROP AGGREGATE` removes an existing aggregate function. To run this command the current user must be the owner of the aggregate function.

Parameters

IF EXISTS Do not throw an error if the aggregate does not exist. A notice is issued in this case.

name The name (optionally schema-qualified) of an existing aggregate function.

argmode The mode of an argument: `IN` or `VARIADIC`. If omitted, the default is `IN`.

argname The name of an argument. Note that `DROP AGGREGATE` does not actually pay any attention to argument names, since only the argument data types are needed to determine the aggregate function's identity.

argtype An input data type on which the aggregate function operates. To reference a zero-argument aggregate function, write `*` in place of the list of argument specifications. To reference an ordered-set aggregate function, write `ORDER BY` between the direct and aggregated argument specifications.

CASCADE Automatically drop objects that depend on the aggregate function (such as views using it) and in turn all objects that depend on those objects.

RESTRICT Refuse to drop the aggregate function if any objects depend on it. This is the default.

Notes

Alternative syntaxes for referencing ordered-set aggregates are described under ALTER AGGREGATE.

Examples

To remove the aggregate function `myavg` for type `integer`:

```
DROP AGGREGATE myavg(integer);
```

To remove the hypothetical-set aggregate function `myrank`, which takes an arbitrary list of ordering columns and a matching list of direct arguments:

```
DROP AGGREGATE myrank(VARIADIC "any" ORDER BY VARIADIC "any");
```

To remove multiple aggregate functions in one command:

```
DROP AGGREGATE myavg(integer), myavg(bigint);
```

Compatibility

There is no `DROP AGGREGATE` statement in the SQL standard.

See Also

ALTER AGGREGATE, CREATE AGGREGATE

Parent topic: SQL Commands

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7.1.99 DROP CAST

Removes a cast.

Synopsis

```
DROP CAST [IF EXISTS] (<sourcetype> AS <targettype>) [CASCADE | RESTRICT]
```

Description

`DROP CAST` will delete a previously defined cast. To be able to drop a cast, you must own the source or the target data type. These are the same privileges that are required to create a cast.

Parameters

IF EXISTS Do not throw an error if the cast does not exist. A notice is issued in this case.

sourcetype The name of the source data type of the cast.

targettype The name of the target data type of the cast.

CASCADE RESTRICT These keywords have no effect since there are no dependencies on casts.

Examples

To drop the cast from type `text` to type `int`:

```
DROP CAST (text AS int);
```

Compatibility

There `DROP CAST` command conforms to the SQL standard.

See Also

CREATE CAST

Parent topic: SQL Commands

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7.1.100 DROP COLLATION

Removes a previously defined collation.

Synopsis

```
DROP COLLATION [ IF EXISTS ] <name> [ CASCADE | RESTRICT ]
```

Description

`DROP COLLATION` removes a previously defined collation. To be able to drop a collation, you must own the collation.

Parameters

`IF EXISTS` Do not throw an error if the collation does not exist. A notice is issued in this case.

name The name of the collation. The collation name can be schema-qualified.

`CASCADE` Automatically drop objects that depend on the collation, and in turn all objects that depend on those objects.

`RESTRICT` Refuse to drop the collation if any objects depend on it. This is the default.

Examples

To drop the collation named `german`:

```
DROP COLLATION german;
```

Compatibility

The `DROP COLLATION` command conforms to the SQL standard, apart from the `IF EXISTS` option, which is a WarehousePG extension.

See Also

ALTER COLLATION, CREATE COLLATION

Parent topic: SQL Commands

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7.1.101 DROP CONVERSION

Removes a conversion.

Synopsis

```
DROP CONVERSION [IF EXISTS] <name> [CASCADE | RESTRICT]
```

Description

`DROP CONVERSION` removes a previously defined conversion. To be able to drop a conversion, you must own the conversion.

Parameters

IF EXISTS Do not throw an error if the conversion does not exist. A notice is issued in this case.

name The name of the conversion. The conversion name may be schema-qualified.

CASCADE RESTRICT These keywords have no effect since there are no dependencies on conversions.

Examples

Drop the conversion named `myname`:

```
DROP CONVERSION myname;
```

Compatibility

There is no `DROP CONVERSION` statement in the SQL standard. The standard has `CREATE TRANSLATION` and `DROP TRANSLATION` statements that are similar to the WarehousePG `CREATE CONVERSION` and `DROP CONVERSION` statements.

See Also

ALTER CONVERSION, CREATE CONVERSION

Parent topic: SQL Commands

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7.1.102 DROP DATABASE

Removes a database.

Synopsis

```
DROP DATABASE [IF EXISTS] <name>
```

Description

`DROP DATABASE` drops a database. It removes the catalog entries for the database and deletes the directory containing the data. It can only be run by the database owner. Also, it cannot be run while you or anyone else are connected to the target database. (Connect to `postgres` or any other database to issue this command.)

> **Caution** `DROP DATABASE` cannot be undone. Use it with care!

Parameters

IF EXISTS Do not throw an error if the database does not exist. A notice is issued in this case.

name The name of the database to remove.

Notes

`DROP DATABASE` cannot be run inside a transaction block.

This command cannot be run while connected to the target database. Thus, it might be more convenient to use the programdropdb instead, which is a wrapper around this command.

Examples

Drop the database named `testdb`:

```
DROP DATABASE testdb;
```

Compatibility

There is no `DROP DATABASE` statement in the SQL standard.

See Also

ALTER DATABASE, CREATE DATABASE

Parent topic: SQL Commands

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7.1.103 DROP DOMAIN

Removes a domain.

Synopsis

```
DROP DOMAIN [IF EXISTS] <name> [, ...]  [CASCADE | RESTRICT]
```

Description

`DROP DOMAIN` removes a previously defined domain. Only the owner of a domain can remove it.

Parameters

IF EXISTS Do not throw an error if the domain does not exist. A notice is issued in this case.

name The name (optionally schema-qualified) of an existing domain.

CASCADE Automatically drop objects that depend on the domain (such as table columns), and in turn all objects that depend on those objects.

RESTRICT Refuse to drop the domain if any objects depend on it. This is the default.

Examples

Remove the domain named `us_postal_code`:

```
DROP DOMAIN us_postal_code;
```

Compatibility

This command conforms to the SQL standard, except for the `IF EXISTS` option, which is a WarehousePG extension.

See Also

ALTER DOMAIN, CREATE DOMAIN

Parent topic: SQL Commands

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7.1.104 DROP EXTENSION

Removes an extension from a WarehousePG.

Synopsis

```
DROP EXTENSION [ IF EXISTS ] <name> [, ...] [ CASCADE | RESTRICT ]
```

Description

`DROP EXTENSION` removes extensions from the database. Dropping an extension causes its component objects to be dropped as well.

> **Note** The supporting extension files that were installed to create the extension (for example, the library and `.control` files) are not deleted. The files must be manually removed from the WarehousePG hosts.

You must own the extension to use `DROP EXTENSION`.

Parameters

IF EXISTS Do not throw an error if the extension does not exist. WarehousePG issues a notice in this case.

name The name of an installed extension.

CASCADE Automatically drop objects that depend on the extension, and in turn all objects that depend on those objects. Refer to the PostgreSQL Dependency Tracking documentation for more information.

> **Important** Before issuing a `DROP EXTENSION` with the `CASCADE` keyword, you should be aware of all object that depend on the extension to avoid unintended consequences.

RESTRICT Refuse to drop an extension if any objects depend on it (other than its own member objects and other extensions listed in the same `DROP` command). This is the default.

Examples

To remove the extension `hstore` from the current database:

```
DROP EXTENSION hstore;
```

This command fails if any of the extension objects are in use in the database. For example, if a table is defined with columns of the `hstore` type. Add the `CASCADE` option to forcibly remove those dependent objects.

Compatibility

`DROP EXTENSION` is a WarehousePG extension.

See Also

CREATE EXTENSION, ALTER EXTENSION

Parent topic: SQL Commands

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7.1.105 DROP EXTERNAL TABLE

Removes an external table definition.

Synopsis

```
DROP EXTERNAL [WEB] TABLE [IF EXISTS] <name> [CASCADE | RESTRICT]
```

Description

`DROP EXTERNAL TABLE` drops an existing external table definition from the database system. The external data sources or files are not deleted. To run this command you must be the owner of the external table.

Parameters

WEB Optional keyword for dropping external web tables.

IF EXISTS Do not throw an error if the external table does not exist. WarehousePG issues a notice in this case.

name The name (optionally schema-qualified) of an existing external table.

CASCADE Automatically drop objects that depend on the external table (such as views).

RESTRICT Refuse to drop the external table if any objects depend on it. This is the default.

Examples

Remove the external table named `staging` if it exists:

```
DROP EXTERNAL TABLE IF EXISTS staging;
```

Compatibility

There is no `DROP EXTERNAL TABLE` statement in the SQL standard.

See Also

CREATE EXTERNAL TABLE, ALTER EXTERNAL TABLE

Parent topic: SQL Commands

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7.1.106 DROP FOREIGN DATA WRAPPER

Removes a foreign-data wrapper.

Synopsis

```
DROP FOREIGN DATA WRAPPER [ IF EXISTS ] <name> [ CASCADE | RESTRICT ]
```

Description

`DROP FOREIGN DATA WRAPPER` removes an existing foreign-data wrapper from the current database. A foreign-data wrapper may be removed only by its owner.

Parameters

IF EXISTS Do not throw an error if the foreign-data wrapper does not exist. WarehousePG issues a notice in this case.

name The name of an existing foreign-data wrapper.

CASCADE Automatically drop objects that depend on the foreign-data wrapper (such as foreign tables and servers), and in turn all objects that depend on those objects.

RESTRICT Refuse to drop the foreign-data wrapper if any object depends on it. This is the default.

Examples

Drop the foreign-data wrapper named `dbi`:

```
DROP FOREIGN DATA WRAPPER dbi;
```

Compatibility

`DROP FOREIGN DATA WRAPPER` conforms to ISO/IEC 9075-9 (SQL/MED). The `IF EXISTS` clause is a WarehousePG extension.

See Also

CREATE FOREIGN DATA WRAPPER, ALTER FOREIGN DATA WRAPPER

Parent topic: SQL Commands

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7.1.107 DROP FOREIGN TABLE

Removes a foreign table.

Synopsis

```
DROP FOREIGN TABLE [ IF EXISTS ] <name> [, ...] [ CASCADE | RESTRICT ]
```

Description

`DROP FOREIGN TABLE` removes an existing foreign table. Only the owner of a foreign table can remove it.

Parameters

IF EXISTS Do not throw an error if the foreign table does not exist. WarehousePG issues a notice in this case.

name The name (optionally schema-qualified) of the foreign table to drop.

CASCADE Automatically drop objects that depend on the foreign table (such as views), and in turn all objects that depend on those objects.

RESTRICT Refuse to drop the foreign table if any objects depend on it. This is the default.

Examples

To destroy two foreign tables, `films` and `distributors`:

```
DROP FOREIGN TABLE films, distributors;
```

Compatibility

`DROP FOREIGN TABLE` conforms to ISO/IEC 9075-9 (SQL/MED), except that the standard only allows one foreign table to be dropped per command. The `IF EXISTS` clause is a WarehousePG extension.

See Also

ALTER FOREIGN TABLE, CREATE FOREIGN TABLE

Parent topic: SQL Commands

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7.1.108 DROP FUNCTION

Removes a function.

Synopsis

```
DROP FUNCTION [IF EXISTS] name ( [ [argmode] [argname] argtype [, ...] ] )
    [CASCADE | RESTRICT]
```

Description

`DROP FUNCTION` removes the definition of an existing function. To run this command the user must be the owner of the function. The argument types to the function must be specified, since several different functions may exist with the same name and different argument lists.

Parameters

IF EXISTS Do not throw an error if the function does not exist. A notice is issued in this case.

name The name (optionally schema-qualified) of an existing function.

argmode The mode of an argument: either `IN` , `OUT` , `INOUT` , or `VARIADIC` . If omitted, the default is `IN` . Note that `DROP FUNCTION` does not actually pay any attention to `OUT` arguments, since only the input arguments are needed to determine the function's identity. So it is sufficient to list the `IN` , `INOUT` , and `VARIADIC` arguments.

argname The name of an argument. Note that `DROP FUNCTION` does not actually pay any attention to argument names, since only the argument data types are needed to determine the function's identity.

argtype The data type(s) of the function's arguments (optionally schema-qualified), if any.

CASCADE Automatically drop objects that depend on the function (such as operators).

RESTRICT Refuse to drop the function if any objects depend on it. This is the default.

Examples

This command removes the square root function:

```
DROP FUNCTION sqrt(integer);
```

Compatibility

A `DROP FUNCTION` statement is defined in the SQL standard, but it is not compatible with this command.

See Also

CREATE FUNCTION, ALTER FUNCTION

Parent topic: SQL Commands

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7.1.109 DROP GROUP

Removes a database role.

Synopsis

```
DROP GROUP [IF EXISTS] <name> [, ...]
```

Description

`DROP GROUP` is an alias for DROP ROLE.

Compatibility

There is no `DROP GROUP` statement in the SQL standard.

See Also

DROP ROLE

Parent topic: SQL Commands

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7.1.110 DROP INDEX

Removes an index.

Synopsis

```
DROP INDEX [ CONCURRENTLY ] [ IF EXISTS ] <name> [, ...] [ CASCADE | RESTRICT ]
```

Description

`DROP INDEX` drops an existing index from the database system. To run this command you must be the owner of the index.

Parameters

CONCURRENTLY Drop the index without locking out concurrent selects, inserts, updates, and deletes on the index's table. A normal `DROP INDEX` acquires an `ACCESS EXCLUSIVE` lock on the table, blocking other accesses until the index drop can be completed. With this option, the command instead waits until conflicting transactions have completed.

There are several caveats to be aware of when using this option. Only one index name can be specified, and the `CASCADE` option is not supported. (Thus, an index that supports a `UNIQUE` or `PRIMARY KEY` constraint cannot be dropped this way.) Also, regular `DROP INDEX` commands can be performed within a transaction block, but `DROP INDEX CONCURRENTLY` cannot.

IF EXISTS Do not throw an error if the index does not exist. A notice is issued in this case.

name The name (optionally schema-qualified) of an index to remove.

CASCADE Automatically drop objects that depend on the index, and in turn all objects that depend on those objects.

RESTRICT Refuse to drop the index if any objects depend on it. This is the default.

Examples

Remove the index `title_idx`:

```
DROP INDEX title_idx;
```

Compatibility

`DROP INDEX` is a WarehousePG language extension. There are no provisions for indexes in the SQL standard.

See Also

ALTER INDEX, CREATE INDEX

Parent topic: SQL Commands

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7.1.111 DROP LANGUAGE

Removes a procedural language.

Synopsis

```
DROP [PROCEDURAL] LANGUAGE [IF EXISTS] <name> [CASCADE | RESTRICT]
```

Description

`DROP LANGUAGE` removes the definition of the previously registered procedural language. You must be a superuser or owner of the language to drop a language.

Parameters

PROCEDURAL Optional keyword - has no effect.

IF EXISTS Do not throw an error if the language does not exist. A notice is issued in this case.

name The name of an existing procedural language. For backward compatibility, the name may be enclosed by single quotes.

CASCADE Automatically drop objects that depend on the language (such as functions written in that language), and in turn all objects that depend on those objects.

RESTRICT Refuse to drop the language if any objects depend on it. This is the default.

Examples

Remove the procedural language `plsample`:

```
DROP LANGUAGE plsample;
```

Compatibility

There is no `DROP LANGUAGE` statement in the SQL standard.

See Also

ALTER LANGUAGE, CREATE LANGUAGE

Parent topic: SQL Commands

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7.1.112 DROP MATERIALIZED VIEW

Removes a materialized view.

Synopsis

```
DROP MATERIALIZED VIEW [ IF EXISTS ] <name> [, ...] [ CASCADE | RESTRICT ]
```

Description

`DROP MATERIALIZED VIEW` drops an existing materialized view. To run this command, you must be the owner of the materialized view.

Parameters

IF EXISTS Do not throw an error if the materialized view does not exist. A notice is issued in this case.

name The name (optionally schema-qualified) of a materialized view to be dropped.

CASCADE Automatically drop objects that depend on the materialized view (such as other materialized views, or regular views), and in turn all objects that depend on those objects.

RESTRICT Refuse to drop the materialized view if any objects depend on it. This is the default.

Examples

This command removes the materialized view called `order_summary`.

```
DROP MATERIALIZED VIEW order_summary;
```

Compatibility

`DROP MATERIALIZED VIEW` is a WarehousePG extension of the SQL standard.

See Also

ALTER MATERIALIZED VIEW, CREATE MATERIALIZED VIEW, REFRESH MATERIALIZED VIEW

Parent topic: SQL Commands

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7.1.113 DROP OPERATOR

Removes an operator.

Synopsis

```
DROP OPERATOR [IF EXISTS] <name> ( {<left_type> | NONE} ,
    {<right_type> | NONE} ) [, ...] [CASCADE | RESTRICT]
```

Description

`DROP OPERATOR` drops an existing operator from the database system. To run this command you must be the owner of the operator.

Parameters

IF EXISTS Do not throw an error if the operator does not exist. A notice is issued in this case.

name The name (optionally schema-qualified) of an existing operator.

left_type The data type of the operator's left operand; write `NONE` if the operator has no left operand.

right_type The data type of the operator's right operand; write `NONE` if the operator has no right operand.

CASCADE Automatically drop objects that depend on the operator (such as views using it), and in turn all objects that depend on those objects.

RESTRICT Refuse to drop the operator if any objects depend on it. This is the default.

Examples

Remove the power operator `a^b` for type `integer`:

```
DROP OPERATOR ^ (integer, integer);
```

Remove the left unary bitwise complement operator `~b` for type `bit`:

```
DROP OPERATOR ~ (none, bit);
```

Remove the right unary factorial operator `x!` for type `bigint`:

```
DROP OPERATOR ! (bigint, none);
```

Remove multiple operators in one command:

```
DROP OPERATOR ~ (none, bit), ! (bigint, none);
```

Compatibility

There is no `DROP OPERATOR` statement in the SQL standard.

See Also

ALTER OPERATOR, CREATE OPERATOR

Parent topic: SQL Commands

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7.1.114 DROP OPERATOR CLASS

Removes an operator class.

Synopsis

```
DROP OPERATOR CLASS [IF EXISTS] <name> USING <index_method> [CASCADE | RESTRICT]
```

Description

`DROP OPERATOR` drops an existing operator class. To run this command you must be the owner of the operator class.

`DROP OPERATOR CLASS` does not drop any of the operators or functions referenced by the class. If there are any indexes depending on the operator class, you will need to specify `CASCADE` for the drop to complete.

Parameters

IF EXISTS Do not throw an error if the operator class does not exist. A notice is issued in this case.

name The name (optionally schema-qualified) of an existing operator class.

index_method The name of the index access method the operator class is for.

CASCADE Automatically drop objects that depend on the operator class (such as indexes), and in turn all objects that depend on those objects.

RESTRICT Refuse to drop the operator class if any objects depend on it. This is the default.

Notes

`DROP OPERATOR CLASS` will not drop the operator family containing the class, even if there is nothing else left in the family (in particular, in the case where the family was implicitly created by `CREATE OPERATOR CLASS`). An empty operator family is harmless, but for the sake of tidiness you might wish to remove the family with `DROP OPERATOR FAMILY`; or perhaps better, use `DROP OPERATOR FAMILY` in the first place.

Examples

Remove the B-tree operator class `widget_ops`:

```
DROP OPERATOR CLASS widget_ops USING btree;
```

This command will not succeed if there are any existing indexes that use the operator class. Add `CASCADE` to drop such indexes along with the operator class.

Compatibility

There is no `DROP OPERATOR CLASS` statement in the SQL standard.

See Also

ALTER OPERATOR CLASS, CREATE OPERATOR CLASS, DROP OPERATOR FAMILY

Parent topic: SQL Commands

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7.1.115 DROP OPERATOR FAMILY

Removes an operator family.

Synopsis

```
DROP OPERATOR FAMILY [IF EXISTS] <name> USING <index_method> [CASCADE | RESTRICT]
```

Description

`DROP OPERATOR FAMILY` drops an existing operator family. To run this command you must be the owner of the operator family.

`DROP OPERATOR FAMILY` includes dropping any operator classes contained in the family, but it does not drop any of the operators or functions referenced by the family. If there are any indexes depending on operator classes within the family, you will need to specify `CASCADE` for the drop to complete.

Parameters

IF EXISTS Do not throw an error if the operator family does not exist. A notice is issued in this case.

name The name (optionally schema-qualified) of an existing operator family.

index_method The name of the index access method the operator family is for.

CASCADE Automatically drop objects that depend on the operator family, and in turn all objects that depend on those objects.

RESTRICT Refuse to drop the operator family if any objects depend on it. This is the default.

Examples

Remove the B-tree operator family `float_ops`:

```
DROP OPERATOR FAMILY float_ops USING btree;
```

This command will not succeed if there are any existing indexes that use the operator family. Add `CASCADE` to drop such indexes along with the operator family.

Compatibility

There is no `DROP OPERATOR FAMILY` statement in the SQL standard.

See Also

ALTER OPERATOR FAMILY, CREATE OPERATOR FAMILY, ALTER OPERATOR CLASS, CREATE OPERATOR CLASS, DROP OPERATOR CLASS

Parent topic: SQL Commands

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7.1.116 DROP OWNED

Removes database objects owned by a database role.

Synopsis

```
DROP OWNED BY { <name> | CURRENT_USER | SESSION_USER } [, ...] [CASCADE | RESTRICT]
```

Description

`DROP OWNED` drops all of the objects in the current database that are owned by one of the specified roles. Any privileges granted to the given roles on objects in the current database or on shared objects (databases, tablespaces) will also be revoked.

Parameters

name The name of a role whose objects will be dropped, and whose privileges will be revoked.

CASCADE Automatically drop objects that depend on the affected objects, and in turn all objects that depend on those objects.

RESTRICT Refuse to drop the objects owned by a role if any other database objects depend on one of the affected objects. This is the default.

Notes

`DROP OWNED` is often used to prepare for the removal of one or more roles. Because `DROP OWNED` only affects the objects in the current database, it is usually necessary to run this command in each database that contains objects owned by a role that is to be removed.

Using the `CASCADE` option may make the command recurse to objects owned by other users.

The REASSIGN OWNED command is an alternative that reassigns the ownership of all the database objects owned by one or more roles. However, `REASSIGN OWNED` does not deal with privileges for other objects.

Databases and tablespaces owned by the role(s) will not be removed.

Examples

Remove any database objects owned by the role named `sally`:

```
DROP OWNED BY sally;
```

Compatibility

The `DROP OWNED` command is a WarehousePG extension.

See Also

REASSIGN OWNED, DROP ROLE

Parent topic: SQL Commands

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7.1.117 DROP POLICY

Removes a row-level security policy from a table.

Synopsis

```
DROP POLICY [ IF EXISTS ] <name> ON <table_name> [ CASCADE | RESTRICT ]
```

Description

`DROP POLICY` removes the specified policy from the table. Note that if the last policy is removed for a table and the table still has row-level security enabled via `ALTER TABLE`, then the default-deny policy will be used. `ALTER TABLE ... DISABLE ROW LEVEL SECURITY` can be used to disable row-level security for a table, whether policies for the table exist or not.

Parameters

IF EXISTS Do not throw an error if the policy does not exist. A notice is issued in this case.

name The name of the policy to drop.

table_name The name (optionally schema-qualified) of the table that the policy is on.

CASCADE RESTRICT These key words have no effect, since there are no dependencies on policies.

Examples

To drop the policy called `p1` on the table named `my_table`:

```
DROP POLICY p1 ON my_table;
```

Compatibility

`DROP POLICY` is a WarehousePG extension to the SQL standard.

See Also

CREATE POLICY, ALTER POLICY

Parent topic: SQL Commands

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7.1.118 DROP PROCEDURE

Removes a procedure.

Synopsis

```
DROP PROCEDURE [IF EXISTS] name ( [ [argmode] [argname] argtype [, ...] ] )
    [CASCADE | RESTRICT]
```

Description

`DROP PROCEDURE` removes the definition of an existing procedure. To run this command the user must be the owner of the procedure. The argument types to the procedure must be specified, since several different procedures may exist with the same name and different argument lists.

Parameters

IF EXISTS Do not throw an error if the procedure does not exist. A notice is issued in this case.

name The name (optionally schema-qualified) of an existing procedure. If no argument list is specified, the name must be unique in its schema.

argmode The mode of an argument: `IN` or `VARIADIC`. If omitted, the default is `IN`.

argname The name of an argument. Note that `DROP PROCEDURE` does not actually pay any attention to argument names, since only the argument data types are needed to determine the procedure's identity.

argtype The data type(s) of the procedure's arguments (optionally schema-qualified), if any.

CASCADE Automatically drop objects that depend on the procedure, and in turn all objects that depend on those objects.

RESTRICT Refuse to drop the procedure if any objects depend on it. This is the default.

Examples

This command removes the procedure named `do_db_maintenance`:

```
DROP PROCEDURE do_db_maintenance();
```

Compatibility

This command conforms to the SQL standard, with these WarehousePG extensions:

- The standard only allows one procedure to be dropped per command.
- The `IF EXISTS` option.
- The ability to specify argument modes and names.

See Also

CREATE PROCEDURE, ALTER PROCEDURE

Parent topic: SQL Commands

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7.1.119 DROP PROTOCOL

Removes a data access protocol from a database.

Synopsis

```
DROP PROTOCOL [IF EXISTS] <name>
```

Description

`DROP PROTOCOL` removes the specified protocol from a database. You specify a protocol name in the `CREATE EXTERNAL TABLE` command to read data from or write data to an external data source.

You must be a superuser or the protocol owner to drop a protocol.

> **Caution** If you drop a data access prococol, external tables that have been defined specifying the protocol will no longer be able to access the external data source.

Parameters

IF EXISTS Do not throw an error if the protocol does not exist. WarehousePG issues a notice in this case.

name The name of an existing data access protocol.

Notes

Dropping a data access protocol, does not drop the protocol's call handlers. You must drop these functions manually.

Be sure to remove any shared libraries that were used by the protocol from the WarehousePG hosts.

Compatibility

`DROP PROTOCOL` is a WarehousePG extension.

See Also

CREATE EXTERNAL TABLE, CREATE PROTOCOL

Parent topic: SQL Commands

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7.1.120 DROP RESOURCE GROUP

Removes a resource group.

Synopsis

```
DROP RESOURCE GROUP <group_name>
```

Description

This command removes a resource group from WarehousePG. Only a superuser can drop a resource group. When you drop a resource group, the memory and CPU resources reserved by the group are returned to WarehousePG.

To drop a role resource group, the group cannot be assigned to any roles, nor can it have any statements pending or running in the group. If you drop a resource group that you created for an external component, the behavior is determined by the external component. For example, dropping a resource group that you assigned to a PL/Container runtime stops running containers in the group.

You cannot drop the pre-defined `admin_group` and `default_group` resource groups.

Parameters

group_name The name of the resource group to remove.

Notes

You cannot submit a `DROP RESOURCE GROUP` command in an explicit transaction or sub-transaction.

Use ALTER ROLE to remove a resource group assigned to a specific user/role.

Perform the following query to view all of the currently active queries for all resource groups:

```
SELECT usename, query, waiting, pid,
    rsgid, rsgname, rsgqueueduration
  FROM pg_stat_activity;
```

To view the resource group assignments, perform the following query on the `pg_roles` and `pg_resgroup` system catalog tables:

```
SELECT rolname, rsgname
  FROM pg_roles, pg_resgroup
  WHERE pg_roles.rolresgroup=pg_resgroup.oid;
```

Examples

Remove the resource group assigned to a role. This operation then assigns the default resource group `default_group` to the role:

```
ALTER ROLE bob RESOURCE GROUP NONE;
```

Remove the resource group named `adhoc` :

```
DROP RESOURCE GROUP adhoc;
```

Compatibility

The `DROP RESOURCE GROUP` statement is a WarehousePG extension.

See Also

ALTER RESOURCE GROUP, CREATE RESOURCE GROUP, ALTER ROLE

Parent topic: SQL Commands

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7.1.121 DROP RESOURCE QUEUE

Removes a resource queue.

Synopsis

```
DROP RESOURCE QUEUE <queue_name>
```

Description

This command removes a resource queue from WarehousePG. To drop a resource queue, the queue cannot have any roles assigned to it, nor can it have any statements waiting in the queue. Only a superuser can drop a resource queue.

Parameters

queue_name The name of a resource queue to remove.

Notes

Use ALTER ROLE to remove a user from a resource queue.

To see all the currently active queries for all resource queues, perform the following query of the `pg_locks` table joined with the `pg_roles` and `pg_resqueue` tables:

```
SELECT rolname, rsqname, locktype, objid, pid,
mode, granted FROM pg_roles, pg_resqueue, pg_locks WHERE
pg_roles.rolresqueue=pg_locks.objid AND
pg_locks.objid=pg_resqueue.oid;
```

To see the roles assigned to a resource queue, perform the following query of the `pg_roles` and `pg_resqueue` system catalog tables:

```
SELECT rolname, rsqname FROM pg_roles, pg_resqueue WHERE
pg_roles.rolresqueue=pg_resqueue.oid;
```

Examples

Remove a role from a resource queue (and move the role to the default resource queue, `pg_default`):

```
ALTER ROLE bob RESOURCE QUEUE NONE;
```

Remove the resource queue named `adhoc`:

```
DROP RESOURCE QUEUE adhoc;
```

Compatibility

The `DROP RESOURCE QUEUE` statement is a WarehousePG extension.

See Also

ALTER RESOURCE QUEUE, CREATE RESOURCE QUEUE, ALTER ROLE

Parent topic: SQL Commands

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7.1.122 DROP ROLE

Removes a database role.

Synopsis

```
DROP ROLE [IF EXISTS] <name> [, ...]
```

Description

`DROP ROLE` removes the specified role(s). To drop a superuser role, you must be a superuser yourself. To drop non-superuser roles, you must have `CREATEROLE` privilege.

A role cannot be removed if it is still referenced in any database; an error will be raised if so. Before dropping the role, you must drop all the objects it owns (or reassign their ownership) and revoke any privileges the role has been granted on other objects. The REASSIGN OWNED and DROP OWNED commands can be useful for this purpose.

However, it is not necessary to remove role memberships involving the role; `DROP ROLE` automatically revokes any memberships of the target role in other roles, and of other roles in the target role. The other roles are not dropped nor otherwise affected.

Parameters

IF EXISTS Do not throw an error if the role does not exist. A notice is issued in this case.

name The name of the role to remove.

Examples

Remove the roles named `sally` and `bob`:

```
DROP ROLE sally, bob;
```

Compatibility

The SQL standard defines `DROP ROLE`, but it allows only one role to be dropped at a time, and it specifies different privilege requirements than WarehousePG uses.

See Also

REASSIGN OWNED, DROP OWNED, CREATE ROLE, ALTER ROLE, SET ROLE

Parent topic: SQL Commands

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7.1.123 DROP ROUTINE

Removes a routine.

Synopsis

```
DROP ROUTINE [IF EXISTS] name ( [ [argmode] [argname] argtype [, ...] ] )
    [CASCADE | RESTRICT]
```

Description

`DROP ROUTINE` removes the definition of an existing routine, which can be an aggregate function, a normal function, or a procedure. Refer to DROP AGGREGATE, DROP FUNCTION, and DROP PROCEDURE for the description of the parameters, more examples, and further details.

Examples

To drop the routine `foo` for type `integer`:

```
DROP ROUTINE foo(integer);
```

This command will work independent of whether `foo` is an aggregate, function, or procedure.

Compatibility

This command conforms to the SQL standard, with these WarehousePG extensions:

- The standard only allows one routine to be dropped per command.
- The `IF EXISTS` option.
- The ability to specify argument modes and names.
- Aggregate functions are an extension.

See Also

DROP AGGREGATE, DROP FUNCTION, DROP PROCEDURE, ALTER ROUTINE

Parent topic: SQL Commands

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7.1.124 DROP RULE

Removes a rewrite rule.

Synopsis

```
DROP RULE [IF EXISTS] <name> ON <table_name> [CASCADE | RESTRICT]
```

Description

`DROP RULE` drops a rewrite rule from a table or view.

Parameters

IF EXISTS Do not throw an error if the rule does not exist. WarehousePG issues a notice in this case.

name The name of the rule to remove.

table_name The name (optionally schema-qualified) of the table or view that the rule applies to.

CASCADE Automatically drop objects that depend on the rule, and in turn all objects that depend on those objects.

RESTRICT Refuse to drop the rule if any objects depend on it. This is the default.

Examples

Remove the rewrite rule `sales_2006` on the table `sales`:

```
DROP RULE sales_2006 ON sales;
```

Compatibility

`DROP RULE` is a WarehousePG extension, as is the entire query rewrite system.

See Also

ALTER RULE, CREATE RULE

Parent topic: SQL Commands

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7.1.125 DROP SCHEMA

Removes a schema.

Synopsis

```
DROP SCHEMA [IF EXISTS] <name> [, ...] [CASCADE | RESTRICT]
```

Description

`DROP SCHEMA` removes schemas from the database.

A schema can be dropped only by its owner or a superuser. Note that the owner can drop the schema (and thereby all contained objects) even if they do not own some of the objects within the schema.

Parameters

IF EXISTS Do not throw an error if the schema does not exist. A notice is issued in this case.

name The name of the schema to remove.

CASCADE Automatically drop objects (tables, functions, etc.) that are contained in the schema, and in turn all objects that depend on those objects.

RESTRICT Refuse to drop the schema if it contains any objects. This is the default.

Notes

Using the `CASCADE` option may result in the command removing objects in other schemas besides the one(s) named.

Examples

Remove the schema `mystuff` from the database, along with everything it contains:

```
DROP SCHEMA mystuff CASCADE;
```

Compatibility

`DROP SCHEMA` is fully conforming with the SQL standard, except that the standard only allows one schema to be dropped per command. Also, the `IF EXISTS` option is a WarehousePG extension.

See Also

CREATE SCHEMA, ALTER SCHEMA

Parent topic: SQL Commands

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7.1.126 DROP SEQUENCE

Removes a sequence.

Synopsis

```
DROP SEQUENCE [IF EXISTS] <name> [, ...] [CASCADE | RESTRICT]
```

Description

`DROP SEQUENCE` removes sequence number generators. You must own the sequence to drop it (or be a superuser).

Parameters

IF EXISTS Do not throw an error if the sequence does not exist. WarehousePG issues a notice in this case.

name The name (optionally schema-qualified) of the sequence to remove.

CASCADE Automatically drop objects that depend on the sequence, and in turn all objects that depend on those objects.

RESTRICT Refuse to drop the sequence if any objects depend on it. This is the default.

Examples

Remove the sequence `myserial`:

```
DROP SEQUENCE myserial;
```

Compatibility

`DROP SEQUENCE` conforms to the SQL standard, except that the standard allows only one sequence to be dropped per command. Also, the `IF EXISTS` option is a WarehousePG extension.

See Also

ALTER SEQUENCE, CREATE SEQUENCE

Parent topic: SQL Commands

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7.1.127 DROP SERVER

Removes a foreign server descriptor.

Synopsis

```
DROP SERVER [ IF EXISTS ] <name> [, ...] [ CASCADE | RESTRICT ]
```

Description

`DROP SERVER` removes an existing foreign server descriptor. The user running this command must be the owner of the server.

Parameters

IF EXISTS Do not throw an error if the server does not exist. WarehousePG issues a notice in this case.

name The name of an existing server.

CASCADE Automatically drop objects that depend on the server (such as user mappings), and in turn all objects that depend on those objects.

RESTRICT Refuse to drop the server if any object depends on it. This is the default.

Examples

Drop the server named `foo` if it exists:

```
DROP SERVER IF EXISTS foo;
```

Compatibility

`DROP SERVER` conforms to ISO/IEC 9075-9 (SQL/MED). The `IF EXISTS` clause is a WarehousePG extension.

See Also

CREATE SERVER, ALTER SERVER

Parent topic: SQL Commands

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7.1.128 DROP STATISTICS

Removes extended statistics.

Synopsis

```
DROP STATISTICS [ IF EXISTS ] <name> [, ...] [ CASCADE | RESTRICT ]
```

Description

`DROP STATISTICS` removes statistics object(s) from the database. Only the statistics object's owner, the schema owner, or a superuser can drop a statistics object.

Parameters

`IF EXISTS` Do not throw an error if the statistics object does not exist. WarehousePG issues a notice in this case.

name The name (optionally schema-qualified) of the statistics object to drop.

CASCADE RESTRICT These key words have no effect, since there are no dependencies on statistics.

Examples

Destroy two statistics objects in different schemas, without failing if they do not exist:

```
DROP STATISTICS IF EXISTS
    accounting.users_uid_creation,
    public.grants_user_role;
```

Compatibility

There is no `DROP STATISTICS` command in the SQL standard.

See Also

ALTER STATISTICS, CREATE STATISTICS

Parent topic: SQL Commands

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7.1.129 DROP TABLE

Removes a table.

Synopsis

```
DROP TABLE [IF EXISTS] <name> [, ...] [CASCADE | RESTRICT]
```

Description

`DROP TABLE` removes tables from the database. Only the table owner, the schema owner, and superuser can drop a table. To empty a table of rows without removing the table definition, useDELETE or TRUNCATE.

`DROP TABLE` always removes any indexes, rules, triggers, and constraints that exist for the target table. However, to drop a table that is referenced by a view, `CASCADE` must be specified. `CASCADE` removes a dependent view entirely.

Parameters

IF EXISTS Do not throw an error if the table does not exist. WarehousePG issues a notice in this case.

name The name (optionally schema-qualified) of the table to remove.

CASCADE Automatically drop objects that depend on the table (such as views), and in turn all objects that depend on those objects.

RESTRICT Refuse to drop the table if any objects depend on it. This is the default.

Examples

Remove the table `mytable`:

```
DROP TABLE mytable;
```

Remove two tables, `films` and `distributors`:

```
DROP TABLE films, distributors;
```

Compatibility

`DROP TABLE` conforms to the SQL standard, except that the standard allows only one table to be dropped per command. Also, the `IF EXISTS` option is a WarehousePG extension.

See Also

ALTER TABLE, CREATE TABLE

Parent topic: SQL Commands

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7.1.130 DROP TABLESPACE

Removes a tablespace.

Synopsis

```
DROP TABLESPACE [IF EXISTS] <name>
```

Description

`DROP TABLESPACE` removes a tablespace from the system.

A tablespace can only be dropped by its owner or a superuser. The tablespace must be empty of all database objects before it can be dropped. It is possible that objects in other databases may still reside in the tablespace even if no objects in the current database are using the tablespace. Also, if the tablespace is listed in the temp_tablespaces setting of any active session, `DROP TABLESPACE` might fail due to temporary files residing in the tablespace.

Parameters

IF EXISTS Do not throw an error if the tablespace does not exist. WarehousePG issues a notice in this case.

name The name of the tablespace to remove.

Notes

You cannot run `DROP TABLESPACE` inside a transaction block.

Run `DROP TABLESPACE` during a period of low activity to avoid issues due to concurrent creation of tables and temporary objects. When a tablespace is dropped, there is a small window in which a table could be created in the tablespace that is currently being dropped. If this occurs, WarehousePG returns a warning. This is an example of the `DROP TABLESPACE` warning.

```
testdb=# DROP TABLESPACE mytest;
WARNING:  tablespace with oid "16415" is not empty  (seg1 192.168.8.145:25433 pid=29023)
WARNING:  tablespace with oid "16415" is not empty  (seg0 192.168.8.145:25432 pid=29022)
WARNING:  tablespace with oid "16415" is not empty
DROP TABLESPACE
```

The table data in the tablespace directory is not dropped. You can use the ALTER TABLE command to change the tablespace defined for the table and move the data to an existing tablespace.

Examples

Remove the tablespace `mystuff`:

```
DROP TABLESPACE mystuff;
```

Compatibility

`DROP TABLESPACE` is a WarehousePG extension.

See Also

CREATE TABLESPACE, ALTER TABLESPACE

Parent topic: SQL Commands

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7.1.131 DROP TEXT SEARCH CONFIGURATION

Removes a text search configuration.

Synopsis

```
DROP TEXT SEARCH CONFIGURATION [ IF EXISTS ] <name> [ CASCADE | RESTRICT ]
```

Description

`DROP TEXT SEARCH CONFIGURATION` drops an existing text search configuration. You must be the owner of the configuration to run this command.

Parameters

IF EXISTS Do not throw an error if the text search configuration does not exist. WarehousePG issues a notice in this case.

name The name (optionally schema-qualified) of an existing text search configuration.

CASCADE Automatically drop objects that depend on the text search configuration, and in turn all objects that depend on those objects.

RESTRICT Refuse to drop the text search configuration if any objects depend on it. This is the default.

Examples

Remove the text search configuration `my_english`:

```
DROP TEXT SEARCH CONFIGURATION my_english;
```

This command will not succeed if there are any existing indexes that reference the configuration in `to_tsvector` calls. Add `CASCADE` to drop such indexes along with the text search configuration.

Compatibility

There is no `DROP TEXT SEARCH CONFIGURATION` statement in the SQL standard.

See Also

ALTER TEXT SEARCH CONFIGURATION, CREATE TEXT SEARCH CONFIGURATION

Parent topic: SQL Commands

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7.1.132 DROP TEXT SEARCH DICTIONARY

Removes a text search dictionary.

Synopsis

```
DROP TEXT SEARCH DICTIONARY [ IF EXISTS ] <name> [ CASCADE | RESTRICT ]
```

Description

`DROP TEXT SEARCH DICTIONARY` drops an existing text search dictionary. You must be the owner of the dictionary to run this command.

Parameters

IF EXISTS Do not throw an error if the text search dictionary does not exist. WarehousePG issues a notice in this case.

name The name (optionally schema-qualified) of an existing text search dictionary.

CASCADE Automatically drop objects that depend on the text search dictionary, and in turn all objects that depend on those objects.

RESTRICT Refuse to drop the text search dictionary if any objects depend on it. This is the default.

Examples

Remove the text search dictionary `english`:

```
DROP TEXT SEARCH DICTIONARY english;
```

This command will not succeed if there are any existing text search configurations that use the dictionary. Add `CASCADE` to drop such configurations along with the dictionary.

Compatibility

There is no `CREATE TEXT SEARCH DICTIONARY` statement in the SQL standard.

See Also

ALTER TEXT SEARCH DICTIONARY, CREATE TEXT SEARCH DICTIONARY

Parent topic: SQL Commands

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7.1.133 DROP TEXT SEARCH PARSER

Removes a text search parser.

Synopsis

```
DROP TEXT SEARCH PARSER [ IF EXISTS ] <name> [ CASCADE | RESTRICT ]
```

Description

`DROP TEXT SEARCH PARSER` drops an existing text search parser. You must be a superuser to use this command.

Parameters

IF EXISTS Do not throw an error if the text search parser does not exist. WarehousePG issues a notice in this case.

name The name (optionally schema-qualified) of an existing text search parser.

CASCADE Automatically drop objects that depend on the text search parser, and in turn all objects that depend on those objects.

RESTRICT Refuse to drop the text search parser if any objects depend on it. This is the default.

Examples

Remove the text search parser `my_parser`:

```
DROP TEXT SEARCH PARSER my_parser;
```

This command will not succeed if there are any existing text search configurations that use the parser. Add `CASCADE` to drop such configurations along with the parser.

Compatibility

There is no `DROP TEXT SEARCH PARSER` statement in the SQL standard.

See Also

ALTER TEXT SEARCH PARSER, CREATE TEXT SEARCH PARSER

Parent topic: SQL Commands

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7.1.134 DROP TEXT SEARCH TEMPLATE

Removes a text search template.

Synopsis

```
DROP TEXT SEARCH TEMPLATE [ IF EXISTS ] <name> [ CASCADE | RESTRICT ]
```

Description

`DROP TEXT SEARCH TEMPLATE` drops an existing text search template. You must be a superuser to use this command.

You must be a superuser to use `ALTER TEXT SEARCH TEMPLATE`.

Parameters

IF EXISTS Do not throw an error if the text search template does not exist. WarehousePG issues a notice in this case.

name The name (optionally schema-qualified) of an existing text search template.

CASCADE Automatically drop objects that depend on the text search template, and in turn all objects that depend on those objects.

RESTRICT Refuse to drop the text search template if any objects depend on it. This is the default.

Examples

Remove the text search template `thesaurus`:

```
DROP TEXT SEARCH TEMPLATE thesaurus;
```

This command will not succeed if there are any existing text search dictionaries that use the template. Add `CASCADE` to drop such dictionaries along with the template.

Compatibility

There is no `DROP TEXT SEARCH TEMPLATE` statement in the SQL standard.

See Also

ALTER TEXT SEARCH TEMPLATE, CREATE TEXT SEARCH TEMPLATE

Parent topic: SQL Commands

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7.1.135 DROP TRANSFORM

Removes a transform.

Synopsis

```
DROP TRANSFORM [IF EXISTS] FOR <type_name> LANGUAGE <lang_name> [CASCADE | RESTRICT]
```

Description

`DROP TRANSFORM` removes a previously defined transform.

To drop a transform, you must own the type and the language. These are the same privileges that are required to create a transform.

Parameters

IF EXISTS Do not throw an error if the transform does not exist. WarehousePG issues a notice in this case.

type_name The name of the data type of the transform.

lang_name The name of the language of the transform.

CASCADE Automatically drop objects that depend on the transform, and in turn all objects that depend on those objects.

RESTRICT Refuse to drop the transform if any objects depend on it. This is the default.

Examples

To drop the transform for type `hstore` and language `plpython3u`:

```
DROP TRANSFORM FOR hstore LANGUAGE
plpython3u;
```

Compatibility

This form of `DROP TRANSFORM` is a WarehousePG extension. See CREATE TRANSFORM for details.

See Also

CREATE TRANSFORM

Parent topic: SQL Commands

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7.1.136 DROP TYPE

Removes a data type.

Synopsis

```
DROP TYPE [IF EXISTS] <name> [, ...] [CASCADE | RESTRICT]
```

Description

`DROP TYPE` will remove a user-defined data type. Only the owner of a type can remove it.

Parameters

IF EXISTS Do not throw an error if the type does not exist. WarehousePG issues a notice in this case.

name The name (optionally schema-qualified) of the data type to remove.

CASCADE Automatically drop objects that depend on the type (such as table columns, functions, operators), and in turn all objects that depend on those objects.

RESTRICT Refuse to drop the type if any objects depend on it. This is the default.

Examples

Remove the data type `box`;

```
DROP TYPE box;
```

Compatibility

This command is similar to the corresponding command in the SQL standard, apart from the `IF EXISTS` option, which is a WarehousePG extension. But note that much of the `CREATE TYPE` command and the data type extension mechanisms in WarehousePG differ from the SQL standard.

See Also

ALTER TYPE, CREATE TYPE

Parent topic: SQL Commands

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7.1.137 DROP USER

Removes a database role.

Synopsis

```
DROP USER [IF EXISTS] <name> [, ...]
```

Description

`DROP USER` is an alias for DROP ROLE.

Compatibility

The `DROP USER` statement is a WarehousePG extension. The SQL standard leaves the definition of users to the implementation.

See Also

DROP ROLE

Parent topic: SQL Commands

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7.1.138 DROP USER MAPPING

Removes a user mapping for a foreign server.

Synopsis

```
DROP USER MAPPING [ IF EXISTS ] { <user_name> | USER | CURRENT_USER | PUBLIC }
    SERVER <server_name>
```

Description

`DROP USER MAPPING` removes an existing user mapping from a foreign server.

The owner of a foreign server can drop user mappings for that server for any user. Also, a user can drop a user mapping for their own user name if they have been granted the `USAGE` privilege on the server.

Parameters

IF EXISTS Do not throw an error if the user mapping does not exist. WarehousePG issues a notice in this case.

user_name User name of the mapping. `CURRENT_USER` and `USER` match the name of the current user. `PUBLIC` is used to match all present and future user names in the system.

server_name Server name of the user mapping.

Examples

Drop the user mapping named `bob`, server `foo` if it exists:

```
DROP USER MAPPING IF EXISTS FOR bob SERVER foo;
```

Compatibility

`DROP SERVER` conforms to ISO/IEC 9075-9 (SQL/MED). The `IF EXISTS` clause is a WarehousePG extension.

See Also

CREATE USER MAPPING, ALTER USER MAPPING

Parent topic: SQL Commands

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7.1.139 DROP VIEW

Removes a view.

Synopsis

```
DROP VIEW [IF EXISTS] <name> [, ...] [CASCADE | RESTRICT]
```

Description

`DROP VIEW` removes an existing view. Only the owner of a view can remove it.

Parameters

IF EXISTS Do not throw an error if the view does not exist. WarehousePG issues a notice in this case.

name The name (optionally schema-qualified) of the view to remove.

CASCADE Automatically drop objects that depend on the view (such as other views), and in turn all objects that depend on those objects.

RESTRICT Refuse to drop the view if any objects depend on it. This is the default.

Examples

Remove the view `topten`:

```
DROP VIEW topten;
```

Compatibility

`DROP VIEW` fully conforms to the SQL standard, except that the standard only allows one view to be dropped per command. Also, the `IF EXISTS` option is a WarehousePG extension.

See Also

CREATE VIEW, ALTER VIEW

Parent topic: SQL Commands

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7.1.140 END

Commits the current transaction.

Synopsis

```
END [WORK | TRANSACTION] [AND [NO] CHAIN]
```

Description

`END` commits the current transaction. All changes made by the transaction become visible to others and are guaranteed to be durable if a crash occurs. This command is a WarehousePG extension that is equivalent toCOMMIT.

Parameters

WORK TRANSACTION Optional keywords. They have no effect.

AND CHAIN If `AND CHAIN` is specified, a new transaction is immediately started with the same transaction characteristics (see SET TRANSACTION) as the just finished one. Otherwise, no new transaction is started.

Notes

Use ROLLBACK to terminate a transaction.

Issuing `END` when not inside a transaction does no harm, but it will provoke a warning message.

Examples

To commit the current transaction and make all changes permanent:

```
END;
```

Compatibility

`END` is a WarehousePG extension that provides functionality equivalent to COMMIT, which is specified in the SQL standard.

See Also

BEGIN, COMMIT, ROLLBACK

Parent topic: SQL Commands

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7.1.141 EXECUTE

Runs a prepared SQL statement.

Synopsis

```
EXECUTE <name> [ (<parameter> [, ...] ) ]
```

Description

`EXECUTE` is used to run a previously prepared statement. Since prepared statements only exist for the duration of a session, the prepared statement must have been created by a `PREPARE` statement run earlier in the current session.

If the `PREPARE` statement that created the statement specified some parameters, a compatible set of parameters must be passed to the `EXECUTE` statement, or else WarehousePG raises an error. Because (unlike functions) prepared statements are not overloaded based on the type or number of their parameters, the name of a prepared statement must be unique within a database session.

For more information on the creation and usage of prepared statements, see PREPARE.

Parameters

name The name of the prepared statement to run.

parameter The actual value of a parameter to the prepared statement. This must be an expression yielding a value that is compatible with the data type of this parameter, as was determined when the prepared statement was created.

Outputs

The command tag returned by `EXECUTE` is that of the prepared statement, and not `EXECUTE`.

Examples

Create a prepared statement for an `INSERT` statement, and then run it:

```
PREPARE fooplan (int, text, bool, numeric) AS
    INSERT INTO foo VALUES($1, $2, $3, $4);
EXECUTE fooplan(1, 'Hunter Valley', 't', 200.00);
```

Compatibility

The SQL standard includes an `EXECUTE` statement, but it is only for use in embedded SQL. This version of the `EXECUTE` statement also uses a somewhat different syntax.

See Also

DEALLOCATE, PREPARE

Parent topic: SQL Commands

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7.1.142 EXPLAIN

Shows the query plan of a statement.

Synopsis

```
EXPLAIN [ ( <option> [, ...] ) ] <statement>
EXPLAIN [ANALYZE] [VERBOSE] <statement>
```

where option can be one of:

```
    ANALYZE [ <boolean> ]
    VERBOSE [ <boolean> ]
    COSTS [ <boolean> ]
    BUFFERS [ <boolean> ]
    TIMING [ <boolean> ]
    FORMAT { TEXT | XML | JSON | YAML }
```

Description

`EXPLAIN` displays the query plan that the WarehousePG or Postgres-based planner generates for the supplied statement. Query plans are a tree plan of nodes. Each node in the plan represents a single operation, such as table scan, join, aggregation or a sort.

Plans should be read from the bottom up as each node feeds rows into the node directly above it. The bottom nodes of a plan are usually table scan operations (sequential, index or bitmap index scans). If the query requires joins, aggregations, or sorts (or other operations on the raw rows) then there will be additional nodes above the scan nodes to perform these operations. The topmost plan nodes are usually the WarehousePG motion nodes (redistribute, explicit redistribute, broadcast, or gather motions). These are the operations responsible for moving rows between the segment instances during query processing.

The output of `EXPLAIN` has one line for each node in the plan tree, showing the basic node type plus the following cost estimates that the planner made for the execution of that plan node:

- **cost** — the planner's guess at how long it will take to run the statement (measured in cost units that are arbitrary, but conventionally mean disk page fetches). Two cost numbers are shown: the start-up cost before the first row can be returned, and the total cost to return all the rows. Note that the total cost assumes that all rows will be retrieved, which may not always be the case (if using `LIMIT` for example).
- **rows** — the total number of rows output by this plan node. This is usually less than the actual number of rows processed or scanned by the plan node, reflecting the estimated selectivity of any `WHERE` clause conditions. Ideally the top-level nodes estimate will approximate the number of rows actually returned, updated, or deleted by the query.
- **width** — total bytes of all the rows output by this plan node.

It is important to note that the cost of an upper-level node includes the cost of all its child nodes. The topmost node of the plan has the estimated total execution cost for the plan. This is this number that the planner seeks to minimize. It is also important to realize that the cost only reflects things that the query optimizer cares about. In particular, the cost does not consider the time spent transmitting result rows to the client.

`EXPLAIN ANALYZE` causes the statement to be actually run, not only planned. The `EXPLAIN ANALYZE` plan shows the actual results along with the planner's estimates. This is useful for seeing whether the planner's estimates are close to reality. In addition to the information shown in the `EXPLAIN` plan, `EXPLAIN ANALYZE` will show the following additional information:

- The total elapsed time (in milliseconds) that it took to run the query.
- The number of *workers* (segments) involved in a plan node operation. Only segments that return rows are counted.
- The maximum number of rows returned by the segment that produced the most rows for an operation. If multiple segments produce an equal number of rows, the one with the longest *time to end* is the one chosen.
- The segment id number of the segment that produced the most rows for an operation.
- For relevant operations, the work_mem used by the operation. If `work_mem` was not sufficient to perform the operation in memory, the plan will show how much data was spilled to disk and how many passes over the data were required for the lowest performing segment. For example:

  ```
  Work_mem used: 64K bytes avg, 64K bytes max (seg0).
  Work_mem wanted: 90K bytes avg, 90K bytes max (seg0) to abate workfile
  I/O affecting 2 workers.
  [seg0] pass 0: 488 groups made from 488 rows; 263 rows written to
  workfile
  [seg0] pass 1: 263 groups made from 263 rows
  ```

- The time (in milliseconds) it took to retrieve the first row from the segment that produced the most rows, and the total time taken to retrieve all rows from that segment. The *<time> to first row* may be omitted if it is the same as the *<time> to end*.

> **Important** Keep in mind that the statement is actually run when `ANALYZE` is used. Although `EXPLAIN ANALYZE` will discard any output that a `SELECT` would return, other side effects of the statement will happen as usual. If you wish to use `EXPLAIN ANALYZE` on a DML statement without letting the command affect your data, use this approach:

```
BEGIN;
EXPLAIN ANALYZE ...;
ROLLBACK;
```

Only the `ANALYZE` and `VERBOSE` options can be specified, and only in that order, without surrounding the option list in parentheses.

Parameters

ANALYZE Carry out the command and show the actual run times and other statistics. This parameter defaults to `FALSE` if you omit it; specify `ANALYZE true` to enable it.

VERBOSE Display additional information regarding the plan. Specifically, include the output column list for each node in the plan tree, schema-qualify table and function names, always label variables in expressions with their range table alias, and always print the name of each trigger for which statistics are displayed. This parameter defaults to `FALSE` if you omit it; specify `VERBOSE true` to enable it.

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COSTS Include information on the estimated startup and total cost of each plan node, as well as the estimated number of rows and the estimated width of each row. This parameter defaults to `TRUE` if you omit it; specify `COSTS false` to deactivate it.

BUFFERS Include information on buffer usage. This parameter may be specified only when `ANALYZE` is also specified. If omitted, the default value is `false`, buffer usage information is not included.

> **Note** WarehousePG does not support specifying `BUFFERS [true]` for distributed queries; ignore any displayed buffer usage information.

TIMING Include actual startup time and time spent in each node in the output. The overhead of repeatedly reading the system clock can slow down the query significantly on some systems, so it may be useful to set this parameter to `FALSE` when only actual row counts, and not exact times, are needed. Run time of the entire statement is always measured, even when node-level timing is turned off with this option. This parameter may only be used when `ANALYZE` is also enabled. It defaults to `TRUE`.

FORMAT Specify the output format, which can be `TEXT`, `XML`, `JSON`, or `YAML`. Non-text output contains the same information as the text output format, but is easier for programs to parse. This parameter defaults to `TEXT`.

boolean Specifies whether the selected option should be turned on or off. You can write `TRUE`, `ON`, or `1` to enable the option, and `FALSE`, `OFF`, or `0` to deactivate it. The boolean value can also be omitted, in which case `TRUE` is assumed.

statement Any `SELECT`, `INSERT`, `UPDATE`, `DELETE`, `VALUES`, `EXECUTE`, `DECLARE`, or `CREATE TABLE AS` statement, whose execution plan you wish to see.

Notes

In order to allow the query optimizer to make reasonably informed decisions when optimizing queries, the `ANALYZE` statement should be run to record statistics about the distribution of data within the table. If you have not done this (or if the statistical distribution of the data in the table has changed significantly since the last time `ANALYZE` was run), the estimated costs are unlikely to conform to the real properties of the query, and consequently an inferior query plan may be chosen.

An SQL statement that is run during the execution of an `EXPLAIN ANALYZE` command is excluded from WarehousePG resource queues.

For more information about query profiling, see "Query Profiling" in the *WarehousePG Administrator Guide*. For more information about resource queues, see "Resource Management with Resource Queues" in the *WarehousePG Administrator Guide*.

Examples

To illustrate how to read an `EXPLAIN` query plan, consider the following example for a very simple query:

```
EXPLAIN SELECT * FROM names WHERE name = 'Joelle';
                                QUERY PLAN
-------------------------------------------------------------------------------
 Gather Motion 3:1  (slice1; segments: 3)  (cost=0.00..431.27 rows=1 width=58)
   ->  Seq Scan on names  (cost=0.00..431.27 rows=1 width=58)
         Filter: (name = 'Joelle'::text)
 Optimizer: GPORCA
(4 rows)
```

If we read the plan from the bottom up, the query optimizer starts by doing a sequential scan of the `names` table. Notice that the `WHERE` clause is being applied as a *filter* condition. This means that the scan operation checks the condition for each row it scans, and outputs only the ones that pass the condition.

The results of the scan operation are passed up to a *gather motion* operation. In WarehousePG, a gather motion is when segments send rows up to the coordinator. In this case we have 3 segment instances sending to 1 coordinator instance (3:1). This operation is working on `slice1` of the parallel query execution plan. In WarehousePG a query plan is divided into *slices* so that portions of the query plan can be worked on in parallel by the segments.

The estimated startup cost for this plan is `00.00` (no cost) and a total cost of `431.27`. The planner is estimating that this query will return one row.

Here is the same query, with cost estimates suppressed:

```
EXPLAIN (COSTS FALSE) SELECT * FROM names WHERE name = 'Joelle';
               QUERY PLAN
-----------------------------------------
 Gather Motion 3:1  (slice1; segments: 3)
   ->  Seq Scan on names
         Filter: (name = 'Joelle'::text)
 Optimizer: GPORCA
(4 rows)
```

Here is the same query, with JSON formatting:

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```
EXPLAIN (FORMAT JSON) SELECT * FROM names WHERE name = 'Joelle';
                 QUERY PLAN
---------------------------------------------
 [                                          +
   {                                        +
     "Plan": {                              +
       "Node Type": "Gather Motion",        +
       "Senders": 3,                        +
       "Receivers": 1,                      +
       "Slice": 1,                          +
       "Segments": 3,                       +
       "Gang Type": "primary reader",       +
       "Startup Cost": 0.00,                +
       "Total Cost": 431.27,                +
       "Plan Rows": 1,                      +
       "Plan Width": 58,                    +
       "Plans": [                           +
         {                                  +
           "Node Type": "Seq Scan",         +
           "Parent Relationship": "Outer",  +
           "Slice": 1,                      +
           "Segments": 3,                   +
           "Gang Type": "primary reader",   +
           "Relation Name": "names",        +
           "Alias": "names",                +
           "Startup Cost": 0.00,            +
           "Total Cost": 431.27,            +
           "Plan Rows": 1,                  +
           "Plan Width": 58,                +
           "Filter": "(name = 'Joelle'::text)"+
         }                                  +
       ]                                    +
     },                                     +
     "Settings": {                          +
       "Optimizer": "(GPORCA) version 3.23.0"     +
     }                                      +
   }                                        +
 ]
(1 row)
```

If there is an index and we use a query with an indexable `WHERE` condition, `EXPLAIN` might show a different plan. This query generates a plan with an index scan, with YAML formatting:

```
EXPLAIN (FORMAT YAML) SELECT * FROM NAMES WHERE LOCATION='Sydney, Australia';
                         QUERY PLAN
------------------------------------------------------------
 - Plan                                                   +
     Node Type: "Gather Motion"                               +
     Senders: 3                                               +
     Receivers: 1                                             +
     Slice: 1                                                 +
     Segments: 3                                              +
     Gang Type: "primary reader"                              +
     Startup Cost: 0.00                                       +
     Total Cost: 10.81                                        +
     Plan Rows: 10000                                         +
     Plan Width: 70                                           +
     Plans                                                +
       - Node Type: "Index Scan"                              +
         Parent Relationship: "Outer"                         +
         Slice: 1                                             +
         Segments: 3                                          +
         Gang Type: "primary reader"                          +
         Scan Direction: "Forward"                            +
         Index Name: "names_idx_loc"                          +
         Relation Name: "names"                               +
         Alias: "names"                                       +
         Startup Cost: 0.00                                   +
         Total Cost: 7.77                                     +
         Plan Rows: 10000                                     +
         Plan Width: 70                                       +
         Index Cond: "(location = 'Sydney, Australia'::text)"+
   Settings                                               +
     Optimizer: " (GPORCA) version 3.23.0"
(1 row)
```

Compatibility

There is no `EXPLAIN` statement defined in the SQL standard.

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See Also

ANALYZE

Parent topic: SQL Commands

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7.1.143 FETCH

Retrieves rows from a query using a cursor.

Synopsis

```
FETCH [ <forward_direction> { FROM | IN } ] <cursor_name>
```

where <forward_direction> can be empty or one of:

```
    NEXT
    FIRST
    ABSOLUTE <count>
    RELATIVE <count>
    <count>
    ALL
    FORWARD
    FORWARD <count>
    FORWARD ALL
```

Description

`FETCH` retrieves rows using a previously-created cursor.

> **Note** You cannot `FETCH` from a `PARALLEL RETRIEVE CURSOR`, you must RETRIEVE the rows from it.

A cursor has an associated position, which is used by `FETCH`. The cursor position can be before the first row of the query result, on any particular row of the result, or after the last row of the result. When created, a cursor is positioned before the first row. After fetching some rows, the cursor is positioned on the row most recently retrieved. If `FETCH` runs off the end of the available rows then the cursor is left positioned after the last row. `FETCH ALL` will always leave the cursor positioned after the last row.

> **Note** Because WarehousePG does not support scrollable cursors, it is not possible to move a cursor position backwards. You can only move a cursor forward in position using `FETCH`.

The forms `NEXT`, `FIRST`, `ABSOLUTE`, `RELATIVE` fetch a single row after moving the cursor appropriately. If there is no such row, an empty result is returned, and the cursor is left positioned before the first row or after the last row as appropriate.

The forms using `FORWARD` retrieve the indicated number of rows moving in the forward direction, leaving the cursor positioned on the last-returned row (or after all rows, if the count exceeds the number of rows available).

`RELATIVE 0` and `FORWARD 0` request fetching the current row without moving the cursor, that is, re-fetching the most recently fetched row. This will succeed unless the cursor is positioned before the first row or after the last row, in which case no row is returned.

> **Note** This page describes usage of cursors at the SQL command level. If you are trying to use cursors inside a PL/pgSQL function, the rules are different. SeePL/pgSQL function.

Parameters

forward_direction Defines the fetch direction and number of rows to fetch. Only forward fetches are allowed in WarehousePG. It can be one of the following:

NEXT Fetch the next row. This is the default if direction is omitted.

FIRST Fetch the first row of the query (same as `ABSOLUTE 1`). Only allowed if it is the first `FETCH` operation using this cursor.

ABSOLUTE count Fetch the specified row of the query. Position after last row if count is out of range. Only allowed if the row specified by count moves the cursor position forward.

RELATIVE count Fetch the specified row of the query count rows ahead of the current cursor position. `RELATIVE 0` re-fetches the current row, if any. Only allowed if count moves the cursor position forward.

count Fetch the next count number of rows (same as `FORWARD count`).

ALL Fetch all remaining rows (same as `FORWARD ALL`).

FORWARD Fetch the next row (same as `NEXT`).

FORWARD count Fetch the next count number of rows. `FORWARD 0` re-fetches the current row.

FORWARD ALL Fetch all remaining rows.

cursor_name The name of an open cursor.

Outputs

On successful completion, a `FETCH` command returns a command tag of the form

```
FETCH <count>
```

The count is the number of rows fetched (possibly zero). Note that in `psql`, the command tag will not actually be displayed, since `psql` displays the fetched rows instead.

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Notes

WarehousePG does not support scrollable cursors, so you can only use `FETCH` to move the cursor position forward.

`ABSOLUTE` fetches are not any faster than navigating to the desired row with a relative move: the underlying implementation must traverse all the intermediate rows anyway.

`DECLARE` is used to define a cursor. Use `MOVE` to change cursor position without retrieving data.

Examples

Start the transaction:

```
BEGIN;
```

Set up a cursor:

```
DECLARE mycursor CURSOR FOR SELECT * FROM films;
```

Fetch the first 5 rows in the cursor `mycursor`:

```
FETCH FORWARD 5 FROM mycursor;
 code  |          title          | did | date_prod  |   kind   |  len
-------+-------------------------+-----+------------+----------+-------
 BL101 | The Third Man           | 101 | 1949-12-23 | Drama    | 01:44
 BL102 | The African Queen       | 101 | 1951-08-11 | Romantic | 01:43
 JL201 | Une Femme est une Femme | 102 | 1961-03-12 | Romantic | 01:25
 P_301 | Vertigo                 | 103 | 1958-11-14 | Action   | 02:08
 P_302 | Becket                  | 103 | 1964-02-03 | Drama    | 02:28
```

Close the cursor and end the transaction:

```
CLOSE mycursor;
COMMIT;
```

Change the `kind` column of the table `films` in the row at the `c_films` cursor's current position:

```
UPDATE films SET kind = 'Dramatic' WHERE CURRENT OF c_films;
```

Compatibility

SQL standard allows cursors only in embedded SQL and in modules. WarehousePG permits cursors to be used interactively.

The variant of `FETCH` described here returns the data as if it were a `SELECT` result rather than placing it in host variables. Other than this point, `FETCH` is fully upward-compatible with the SQL standard.

The `FETCH` forms involving `FORWARD`, as well as the forms `FETCH` count and `FETCH ALL`, in which `FORWARD` is implicit, are WarehousePG extensions. `BACKWARD` is not supported.

The SQL standard allows only `FROM` preceding the cursor name; the option to use `IN`, or to leave them out altogether, is an extension.

See Also

DECLARE, CLOSE, MOVE

Parent topic: SQL Commands

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7.1.144 GRANT

Defines access privileges.

Synopsis

```
GRANT { {SELECT | INSERT | UPDATE | DELETE | REFERENCES |
TRIGGER | TRUNCATE } [, ...] | ALL [PRIVILEGES] }
    ON { [TABLE] [[[ONLY] <table_name> [, ...]] [, ...]]
         | ALL TABLES IN SCHEMA <schema_name> [, ...] }
    TO <role_specification> [, ...] [ WITH GRANT OPTION ]

GRANT { { SELECT | INSERT | UPDATE | REFERENCES } ( <column_name> [, ...] )
    [, ...] | ALL [ PRIVILEGES ] ( <column_name> [, ...] ) }
    ON [TABLE] [[[ONLY] <table_name> [, ...]] [, ...]]
    TO <role_specification> [, ...] [ WITH GRANT OPTION ]

GRANT { {USAGE | SELECT | UPDATE} [, ...] | ALL [PRIVILEGES] }
    ON { SEQUENCE <sequence_name> [, ...]
         | ALL SEQUENCES IN SCHEMA <schema_name> [, ...] }
    TO <role_specification> [, ...] [ WITH GRANT OPTION ]

GRANT { {CREATE | CONNECT | TEMPORARY | TEMP} [, ...] | ALL
[PRIVILEGES] }
    ON DATABASE <database_name> [, ...]
    TO <role_specification> [, ...] [ WITH GRANT OPTION ]

GRANT { USAGE | ALL [ PRIVILEGES ] }
    ON DOMAIN <domain_name> [, ...]
    TO <role_specification> [, ...] [ WITH GRANT OPTION ]

GRANT { USAGE | ALL [ PRIVILEGES ] }
    ON FOREIGN DATA WRAPPER <fdw_name> [, ...]
    TO <role_specification> [, ...] [ WITH GRANT OPTION ]

GRANT { USAGE | ALL [ PRIVILEGES ] }
    ON FOREIGN SERVER <server_name> [, ...]
    TO <role_specification> [, ...] [ WITH GRANT OPTION ]

GRANT { EXECUTE | ALL [PRIVILEGES] }
    ON { { FUNCTION | PROCEDURE | ROUTINE } <routine_name> [ ( [ [ <argmode> ] [ <argname> ] <argtype> [, ...] ] ) ] [, ...]
        | ALL { FUNCTIONS | PROCEDURES | ROUTINES }  IN SCHEMA <schema_name> [, ...] }
    TO <role_specification> [, ...] [ WITH GRANT OPTION ]

GRANT { USAGE | ALL [PRIVILEGES] }
    ON LANGUAGE <lang_name> [, ...]
    TO <role_specification> [, ...] [ WITH GRANT OPTION ]

GRANT { { CREATE | USAGE } [, ...] | ALL [PRIVILEGES] }
    ON SCHEMA <schema_name> [, ...]
    TO <role_specification> [, ...] [ WITH GRANT OPTION ]

GRANT { CREATE | ALL [PRIVILEGES] }
    ON TABLESPACE <tablespace_name> [, ...]
    TO <role_specification> [ WITH GRANT OPTION ]

GRANT { USAGE | ALL [ PRIVILEGES ] }
    ON TYPE <type_name> [, ...]
    TO <role_specification> [, ...] [ WITH GRANT OPTION ]

GRANT <role_name> [, ...] TO <role_specification> [, ...]
    [ WITH ADMIN OPTION ]
    [ GRANTED BY <role_specification> ]

GRANT { SELECT | INSERT | ALL [PRIVILEGES] }
    ON PROTOCOL <protocolname>
    TO <username>

where <role_specification> can be:

    [ GROUP ] <role_name>
  | PUBLIC
  | CURRENT_USER
  | SESSION_USER
```

Description

The `GRANT` command has two basic variants: one that grants privileges on a database object (table, column, view, foreign table, sequence, database, foreign-data wrapper, foreign server, function, procedural language, schema, or tablespace), and one that grants membership in a role. These variants are similar in many ways, but they are different enough to be described separately.

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GRANT on Database Objects

This variant of the `GRANT` command gives specific privileges on a database object to one or more roles. These privileges are added to those already granted, if any.

The keyword `PUBLIC` indicates that the privileges are to be granted to all roles, including those that may be created later. `PUBLIC` may be thought of as an implicitly defined group-level role that always includes all roles. Any particular role will have the sum of privileges granted directly to it, privileges granted to any role it is presently a member of, and privileges granted to `PUBLIC`.

If `WITH GRANT OPTION` is specified, the recipient of the privilege may in turn grant it to others. Without a grant option, the recipient cannot do that. Grant options cannot be granted to `PUBLIC`.

There is no need to grant privileges to the owner of an object (usually the role that created it), as the owner has all privileges by default. (The owner could, however, choose to revoke some of their own privileges for safety.) it The right to drop an object, or to alter its definition in any way is not treated as a grantable privilege; it is inherent in the owner, and cannot be granted or revoked. (However, a similar effect can be obtained by granting or revoking membership in the role that owns the object; see below.) The owner implicitly has all grant options for the object, too.

The possible privileges are:

- `SELECT`
- `INSERT`
- `UPDATE`
- `DELETE`
- `TRUNCATE`
- `REFERENCES`
- `TRIGGER`
- `CREATE`
- `CONNECT`
- `TEMPORARY`, `TEMP`
- `EXECUTE`
- `USAGE`
- `ALL PRIVILEGES`

The `FUNCTION` syntax works for plain functions, aggregate functions, and window functions, but not for procedures; use `PROCEDURE` for those. Alternatively, use `ROUTINE` to refer to a function, aggregate function, window function, or procedure regardless of its precise type.

There is also an option to grant privileges on all objects of the same type within one or more schemas. This functionality is currently supported only for tables, sequences, functions, and procedures. `ALL TABLES` also affects views and foreign tables, just like the specific-object `GRANT` command. `ALL FUNCTIONS` also affects aggregate and window functions, but not procedures, again just like the specific-object `GRANT` command. Use `ALL ROUTINES` to include procedures.

GRANT on Roles

This variant of the `GRANT` command grants membership in a role to one or more other roles. Membership in a role is significant because it conveys the privileges granted to a role to each of its members.

If `WITH ADMIN OPTION` is specified, the member may in turn grant membership in the role to others, and revoke membership in the role as well. Without the admin option, ordinary users cannot do that. A role is not considered to hold `WITH ADMIN OPTION` on itself, but it may grant or revoke membership in itself from a database session where the session user matches the role. Database superusers can grant or revoke membership in any role to anyone. Roles having `CREATEROLE` privilege can grant or revoke membership in any role that is not a superuser.

If `GRANTED BY` is specified, the grant is recorded as having been done by the specified role. Only database superusers may use this option, except when it names the same role executing the command.

Unlike the case with privileges, membership in a role cannot be granted to `PUBLIC`. Note also that this form of the command does not allow the noise word `GROUP` in role_specification.

GRANT on Partitioned Tables

By default, when you grant privileges to a partitioned table, WarehousePG recurses the operation to its child tables. To direct WarehousePG to perform the `GRANT` on the partitioned table only, specify the `ONLY <table_name>` clause.

GRANT on Protocols

You can also use the `GRANT` command to specify which users can access a trusted protocol. (If the protocol is not trusted, you cannot give any other user permission to use it to read or write data.)

- To allow a user to create a readable external table with a trusted protocol:

```
GRANT SELECT ON PROTOCOL <protocolname> TO <username>
```

- To allow a user to create a writable external table with a trusted protocol:

```
GRANT INSERT ON PROTOCOL <protocolname> TO <username>
```

- To allow a user to create both readable and writable external table with a trusted protocol:

```
GRANT ALL ON PROTOCOL <protocolname> TO <username>
```

You can also use this command to grant users permissions to create and use `s3` and `pxf` external tables. However, external tables of type `http`, `https`, `gpfdist`, and `gpfdists`, are implemented internally in WarehousePG instead of as custom protocols. For these types, use the `CREATE ROLE` or `ALTER ROLE` command to set the `CREATEEXTTABLE` or `NOCREATEEXTTABLE` attribute for each user. See CREATE ROLE for syntax and examples.

Parameters

SELECT Allows `SELECT` from any column, or the specific columns listed, of the specified table, view, or sequence. Also allows the use of `COPY TO`. This privilege is also needed to reference existing column values in `UPDATE` or `DELETE`.

INSERT Allows `INSERT` of a new row into the specified table. If specific columns are listed, only those columns may be assigned to in the `INSERT` command (other columns will receive default values). Also allows `COPY FROM`.

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UPDATE Allows `UPDATE` of any column, or the specific columns listed, of the specified table. `SELECT ... FOR UPDATE` and `SELECT ... FOR SHARE` also require this privilege on at least one column, (as well as the `SELECT` privilege). For sequences, this privilege allows the use of the `nextval()` and `setval()` functions.

DELETE Allows `DELETE` of a row from the specified table.

REFERENCES This keyword is accepted, although foreign key constraints are currently not supported in WarehousePG. To create a foreign key constraint, it is necessary to have this privilege on both the referencing and referenced columns. The privilege may be granted for all columns of a table, or just specific columns.

TRIGGER Allows the creation of a trigger on the specified table.

```
> **Note** WarehousePG does not support triggers.
```

TRUNCATE Allows `TRUNCATE` of all rows from the specified table.

CREATE For databases, allows new schemas to be created within the database.

For schemas, allows new objects to be created within the schema. To rename an existing object, you must own the object and have this privilege for the containing schema.

For tablespaces, allows tables and indexes to be created within the tablespace, and allows databases to be created that have the tablespace as their default tablespace. (Note that revoking this privilege will not alter the placement of existing objects.)

CONNECT Allows the user to connect to the specified database. This privilege is checked at connection startup (in addition to checking any restrictions imposed by `pg_hba.conf`).

TEMPORARY TEMP Allows temporary tables to be created while using the database.

EXECUTE Allows the use of the specified function and the use of any operators that are implemented on top of the function. This is the only type of privilege that is applicable to functions. (This syntax works for aggregate functions, as well.)

USAGE For procedural languages, allows the use of the specified language for the creation of functions in that language. This is the only type of privilege that is applicable to procedural languages.

For schemas, allows access to objects contained in the specified schema (assuming that the objects' own privilege requirements are also met). Essentially this allows the grantee to look up objects within the schema.

For sequences, this privilege allows the use of the `currval()` and `nextval()` function.

For types and domains, this privilege allows the use of the type or domain in the creation of tables, functions, and other schema objects. (Note that it does not control general "usage" of the type, such as values of the type appearing in queries. It only prevents objects from being created that depend on the type. The main purpose of the privilege is controlling which users create dependencies on a type, which could prevent the owner from changing the type later.)

For foreign-data wrappers, this privilege enables the grantee to create new servers using that foreign-data wrapper.

For servers, this privilege enables the grantee to create foreign tables using the server, and also to create, alter, or drop their own user's user mappings associated with that server.

ALL PRIVILEGES Grant all of the available privileges at once. The `PRIVILEGES` key word is optional in WarehousePG, though it is required by strict SQL.

PUBLIC A special group-level role that denotes that the privileges are to be granted to all roles, including those that may be created later.

WITH GRANT OPTION The recipient of the privilege may in turn grant it to others.

WITH ADMIN OPTION The member of a role may in turn grant membership in the role to others.

Notes

The REVOKE command is used to revoke access privileges.

WarehousePG unifies the concepts of users and groups into a single kind of entity called a role. It is therefore not necessary to use the keyword `GROUP` to identify whether a grantee is a user or a group. `GROUP` is still allowed in the command, but it is a noise word.

A user may perform `SELECT`, `INSERT`, and so forth, on a column if they hold that privilege for either the specific column or the whole table. Granting the privilege at the table level and then revoking it for one column does not do what you might wish: the table-level grant is unaffected by a column-level operation.

When a non-owner of an object attempts to `GRANT` privileges on the object, the command will fail outright if the user has no privileges whatsoever on the object. As long as some privilege is available, the command will proceed, but it will grant only those privileges for which the user has grant options. The `GRANT ALL PRIVILEGES` forms will issue a warning message if no grant options are held, while the other forms will issue a warning if grant options for any of the privileges specifically named in the command are not held. (In principle these statements apply to the object owner as well, but since the owner is always treated as holding all grant options, the cases can never occur.)

Database superusers can access all objects regardless of object privilege settings. This is comparable to the rights of `root` in a Unix system. As with `root`, it's unwise to operate as a superuser except when absolutely necessary. One exception to this rule is view objects. Access to tables referenced in the view is determined by permissions of the view owner not the current user (even if the current user is a superuser).

If a superuser chooses to issue a `GRANT` or `REVOKE` command, the command is performed as though it were issued by the owner of the affected object. In particular, privileges granted via such a command will appear to have been granted by the object owner. (For role membership, the membership appears to have been granted by the containing role itself.)

`GRANT` and `REVOKE` can also be done by a role that is not the owner of the affected object, but is a member of the role that owns the object, or is a member of a role that holds privileges `WITH GRANT OPTION` on the object. In this case the privileges will be recorded as having been granted by the role that actually owns the object or holds the privileges `WITH GRANT OPTION`. For example, if table `t1` is owned by role `g1`, of which role `u1` is a member, then `u1` can grant privileges on `t1` to `u2`, but those privileges will appear to have been granted directly by `g1`. Any other member of role `g1` could revoke them later.

If the role executing `GRANT` holds the required privileges indirectly via more than one role membership path, it is unspecified which containing role will be recorded as having done the grant. In such cases it is best practice to use `SET ROLE` to become the specific role you want to do the `GRANT` as.

Granting permission on a table does not automatically extend permissions to any sequences used by the table, including sequences tied to `SERIAL` columns. Permissions on a sequence must be set separately.

The `GRANT` command cannot be used to set privileges for the protocols `file`, `gpfdist`, or `gpfdists`. These protocols are implemented internally in WarehousePG. Instead, use the CREATE ROLE or ALTER ROLE command to set the `CREATEEXTTABLE` attribute for the role.

Use `psql`'s `\dp` meta-command to obtain information about existing privileges for tables and columns. There are other `\d` meta-commands that you can use to display the privileges of non-table objects.

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Examples

Grant insert privilege to all roles on table `mytable`:

```
GRANT INSERT ON mytable TO PUBLIC;
```

Grant all available privileges to user `manuel` on view `kinds`:

```
GRANT ALL PRIVILEGES ON kinds TO manuel;
```

Note that while the above will indeed grant all privileges if run by a superuser or the owner of `kinds`, when run by someone else it will only grant those permissions for which the granting role has grant options.

Grant membership in role `admins` to user `joe`:

```
GRANT admins TO joe;
```

Compatibility

According to the SQL standard, the `PRIVILEGES` key word in `ALL PRIVILEGES` is required, but it is optional in WarehousePG. The SQL standard does not support setting the privileges on more than one object per command.

WarehousePG allows an object owner to revoke their own ordinary privileges: for example, a table owner can make the table read-only to theirself by revoking their own `INSERT`, `UPDATE`, `DELETE`, and `TRUNCATE` privileges. This is not possible according to the SQL standard. WarehousePG treats the owner's privileges as having been granted by the owner to the owner; therefore they can revoke them too. In the SQL standard, the owner's privileges are granted by an assumed *system* entity. Not being *system*, the owner cannot revoke these rights.

The SQL standard allows the `GRANTED BY` option to be used in all forms of `GRANT`. WarehousePG only supports it when granting role membership, and even then only superusers may use it in nontrivial ways.

The SQL standard provides for a `USAGE` privilege on other kinds of objects: character sets, collations, translations.

In the SQL standard, sequences only have a `USAGE` privilege, which controls the use of the `NEXT VALUE FOR` expression, which is equivalent to the function `nextval()` in WarehousePG. The sequence privileges `SELECT` and `UPDATE` are WarehousePG extensions. The application of the sequence `USAGE` privilege to the `currval()` function is also a WarehousePG extension (as is the function itself).

Privileges on databases, tablespaces, schemas, and languages are WarehousePG extensions.

See Also

ALTER DEFAULT PRIVILEGES, REVOKE

Parent topic: SQL Commands

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7.1.145 IMPORT FOREIGN SCHEMA

Imports table definitions from a foreign server.

Synopsis

```
IMPORT FOREIGN SCHEMA <remote_schema>
    [ { LIMIT TO | EXCEPT } ( <table_name> [, ...] ) ]
    FROM SERVER <server_name>
    INTO <local_schema>
    [ OPTIONS ( <option> '<value>' [, ... ] ) ]
```

Description

`IMPORT FOREIGN SCHEMA` creates foreign tables that represent tables existing on a foreign server. The new foreign tables will be owned by the user issuing the command and are created with the correct column definitions and options to match the remote tables.

By default, all tables and views existing in a particular schema on the foreign server are imported. Optionally, the list of tables can be limited to a specified subset, or specific tables can be excluded. The new foreign tables are all created in the target schema, which must already exist.

To use `IMPORT FOREIGN SCHEMA`, the user must have `USAGE` privilege on the foreign server, as well as `CREATE` privilege on the target schema.

Support for importing foreign schemas is foreign-data wrapper-specific.

Parameters

remote_schema The remote schema to import from. The specific meaning of a remote schema depends on the foreign data wrapper in use.

LIMIT TO (table_name [, ...]) Import only foreign tables matching one of the given table names. Other tables existing in the foreign schema will be ignored.

EXCEPT (table_name [, ...]) Exclude specified foreign tables from the import. All tables existing in the foreign schema will be imported except the ones listed here.

server_name The name of the foreign server from which to import the table definitions.

local_schema The schema in which WarehousePG will create the imported foreign tables.

OPTIONS (option 'value' [, ...]) The options to be used during the import. The allowed option names and values are specific to each foreign-data wrapper.

Examples

Import table definitions from a remote schema `foreign_films` on server `film_server`, creating the foreign tables in local schema `films`:

```
IMPORT FOREIGN SCHEMA foreign_films
    FROM SERVER film_server INTO films;
```

As above, but import only the two tables `actors` and `directors` (if they exist):

```
IMPORT FOREIGN SCHEMA foreign_films LIMIT TO (actors, directors)
    FROM SERVER film_server INTO films;
```

Compatibility

The `IMPORT FOREIGN SCHEMA` command conforms to the SQL standard, except that the `OPTIONS` clause is a WarehousePG extension.

See Also

CREATE FOREIGN TABLE, CREATE SERVER

Parent topic: SQL Commands

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7.1.146 INSERT

Creates new rows in a table.

Synopsis

```
[ WITH [ RECURSIVE ] <with_query> [, ...] ]
INSERT INTO <table_name> [ AS <alias> ] [( <column_name> [, ...] )]
   [ OVERRIDING { SYSTEM | USER } VALUE ]
   {DEFAULT VALUES | VALUES ( {<expression> | DEFAULT} [, ...] ) [, ...] | <query>}
   [ ON CONFLICT [ <conflict_target> ] <conflict_action> ]
   [RETURNING * | <output_expression> [ [AS] <output_name> ] [, ...]]

where <conflict_target> can be one of:

    ( { <index_column_name> | ( <index_expression> ) } [ COLLATE <collation> ] [ <opclass> ] [, ...] )
    [ WHERE <index_predicate> ]
    ON CONSTRAINT <constraint_name>

and <conflict_action> is one of:

    DO NOTHING
    DO UPDATE SET { <column_name> = { <expression> | DEFAULT } |
                    ( <column_name> [, ...] ) = [ ROW ] ( { <expression> | DEFAULT } [, ...] ) |
                    ( <column_name> [, ...] ) = ( sub-SELECT )
                  } [, ...]
              [ WHERE <condition> ]
```

Description

`INSERT` inserts new rows into a table. One can insert one or more rows specified by value expressions, or zero or more rows resulting from a query.

The target column names may be listed in any order. If no list of column names is given at all, the default is the columns of the table in their declared order; or the first *N* column names, if there are only *N* columns supplied by the `VALUES` clause or query. The values supplied by the `VALUES` clause or query are associated with the explicit or implicit column list left-to-right.

Each column not present in the explicit or implicit column list will be filled with a default value, either its declared default value or null if there is no default.

If the expression for any column is not of the correct data type, WarehousePG attempts automatic type conversion.

`INSERT` into tables that lack unique indexes will not be blocked by concurrent activity. Tables with unique indexes might block if concurrent sessions perform actions that lock or modify rows matching the unique index values being inserted; the details are covered in Index Uniqueness Checks in the PostgreSQL documentation. `ON CONFLICT` can be used to specify an alternative action to raising a unique constraint or exclusion constraint violation error. (See ON CONFLICT Clause below.)

The optional `RETURNING` clause causes `INSERT` to compute and return value(s) based on each row actually inserted (or updated, if an `ON CONFLICT DO UPDATE` clause was used). This is primarily useful for obtaining values that were supplied by defaults, such as a serial sequence number. However, any expression using the table's columns is allowed. The syntax of the `RETURNING` list is identical to that of the output list of `SELECT`. Only rows that were successfully inserted or updated will be returned. For example, if a row was locked but not updated because an `ON CONFLICT DO UPDATE ... WHERE` clause condition was not satisfied, the row will not be returned.

You must have `INSERT` privilege on a table in order to insert into it. If `ON CONFLICT DO UPDATE` is present, `UPDATE` privilege on the table is also required.

When a column list is specified, you only need `INSERT` privilege on the listed columns. Similarly, when `ON CONFLICT DO UPDATE` is specified, you only need `UPDATE` privilege on the column(s) that are listed to be updated. However, `ON CONFLICT DO UPDATE` also requires `SELECT` privilege on any column whose values are read in the `ON CONFLICT DO UPDATE` expressions or condition.

Use of the `RETURNING` clause requires `SELECT` privilege on all columns mentioned in `RETURNING`. If you use the query clause to insert rows from a query, you must have `SELECT` privilege on any table or column referenced in the query.

Parameters

Inserting

This section covers parameters that may be used when only inserting new rows. Parameters exclusively used with the `ON CONFLICT` clause are described separately.

with_query The `WITH` clause allows you to specify one or more subqueries that can be referenced by name in the `INSERT` query. See WITH Queries (Common Table Expressions) and SELECT for details.

It is possible for the query (`SELECT` statement) to also contain a `WITH` clause. In such a case both sets of with_query can be referenced within the `INSERT` query, but the second one takes precedence since it is more closely nested.

table_name The name (optionally schema-qualified) of an existing table.

alias A substitute name for table_name. When an alias is provided, it completely hides the actual name of the table. This is particularly useful when `ON CONFLICT DO UPDATE` targets a table named `excluded`, since that will otherwise be taken as the name of the special table representing the row proposed for insertion.

column_name The name of a column in the table named by table_name. The column name can be qualified with a subfield name or array subscript, if needed. (Inserting into only some fields of a composite column leaves the other fields null.) When referencing a column with `ON CONFLICT DO UPDATE`, do not include the table's name in the specification of a target column. For example, `INSERT INTO table_name ... ON CONFLICT DO UPDATE SET table_name.col = 1` is invalid (this follows the general behavior for `UPDATE`).

OVERRIDING SYSTEM VALUE Without this clause, it is an error to specify an explicit value (other than `DEFAULT`) for an identity column defined as `GENERATED ALWAYS`. This clause overrides that restriction.

OVERRIDING USER VALUE If this clause is specified, then any values supplied for identity columns defined as `GENERATED BY DEFAULT` are ignored and the default sequence-generated values are applied.

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This clause is useful for example when copying values between tables. Writing `INSERT INTO tbl2 OVERRIDING USER VALUE SELECT * FROM tbl1` will copy from `tbl1` all columns that are not identity columns in `tbl2` while values for the identity columns in `tbl2` will be generated by the sequences associated with `tbl2`.

DEFAULT VALUES All columns will be filled with their default values. (An `OVERRIDING` clause is not permitted in this form.)

expression An expression or value to assign to the corresponding column.

DEFAULT The corresponding column will be filled with its default value.

query A query (`SELECT` statement) that supplies the rows to be inserted. Refer to the SELECT statement for a description of the syntax.

output_expression An expression to be computed and returned by the `INSERT` command after each row is inserted or updated. The expression can use any column names of the table named by table_name. Write `*` to return all columns of the inserted row(s).

output_name A name to use for a returned column.

To insert data into a partitioned table, you specify the root partitioned table, the table created with the `CREATE TABLE` command. You also can specify a leaf partition in an `INSERT` command. An error is returned if the data is not valid for the specified leaf partition.

For a partitioned table, all the child tables are locked during the `INSERT` operation when the Global Deadlock Detector is not enabled (the default). Only some of the leaf partitions are locked when the Global Deadlock Detector is enabled. For information about the Global Deadlock Detector, see Global Deadlock Detector.

ON CONFLICT Clause

The optional `ON CONFLICT` clause specifies an alternative action to raising a unique violation or exclusion constraint violation error. For each individual row proposed for insertion, either the insertion proceeds, or, if an arbiter constraint or index specified by conflict_target is violated, the alternative conflict_action is taken. `ON CONFLICT DO NOTHING` simply avoids inserting a row as its alternative action. `ON CONFLICT DO UPDATE` updates the existing row that conflicts with the row proposed for insertion as its alternative action.

conflict_target can perform unique index inference. When performing inference, it consists of one or more index_column_name columns and/or index_expression expressions, and an optional index_predicate. All table_name unique indexes that, without regard to order, contain exactly the conflict_target-specified columns/expressions are inferred (chosen) as arbiter indexes. If an index_predicate is specified, it must, as a further requirement for inference, satisfy arbiter indexes. Note that this means a non-partial unique index (a unique index without a predicate) will be inferred (and thus used by `ON CONFLICT`) if such an index satisfying every other criteria is available. If an attempt at inference is unsuccessful, WarehousePG raises an error.

`ON CONFLICT DO UPDATE` guarantees an atomic `INSERT` or `UPDATE` outcome; provided there is no independent error, one of those two outcomes is guaranteed, even under high concurrency. This is also known as *UPSERT*—`UPDATE` or `INSERT`.

> **NOTE** `ON CONFLICT DO UPDATE` (or `UPSERT`) is available for heap tables only.

conflict_target Specifies which conflicts `ON CONFLICT` takes the alternative action on by choosing arbiter indexes. Either performs unique index inference, or names a constraint explicitly. For `ON CONFLICT DO NOTHING`, it is optional to specify a conflict_target; when omitted, conflicts with all usable constraints (and unique indexes) are handled. For `ON CONFLICT DO UPDATE`, a conflict_target must be provided.

conflict_action conflict_action specifies an alternative `ON CONFLICT` action. It can be either `DO NOTHING`, or a `DO UPDATE` clause specifying the exact details of the `UPDATE` action to be performed in case of a conflict. The `SET` and `WHERE` clauses in `ON CONFLICT DO UPDATE` have access to the existing row using the table's name (or an alias), and to the row proposed for insertion using the special excluded table. `SELECT` privilege is required on any column in the target table where corresponding excluded columns are read.

Note that the effects of all per-row `BEFORE INSERT` triggers are reflected in excluded values, since those effects may have contributed to the row being excluded from insertion.

index_column_name The name of a table_name column. Used to infer arbiter indexes. Follows `CREATE INDEX` format. `SELECT` privilege on index_column_name is required.

index_expression Similar to index_column_name, but used to infer expressions on table_name columns appearing within index definitions (not simple columns). Follows `CREATE INDEX` format. `SELECT` privilege on any column appearing within index_expression is required.

collation When specified, mandates that corresponding index_column_name or index_expression use a particular collation in order to be matched during inference. Typically this is omitted, as collations usually do not affect whether or not a constraint violation occurs. Follows `CREATE INDEX` format.

opclass When specified, mandates that corresponding index_column_name or index_expression use particular operator class in order to be matched during inference. Typically this is omitted, as the equality semantics are often equivalent across a type's operator classes anyway, or because it's sufficient to trust that the defined unique indexes have the pertinent definition of equality. Follows `CREATE INDEX` format.

index_predicate Used to allow inference of partial unique indexes. Any indexes that satisfy the predicate (which need not actually be partial indexes) can be inferred. Follows `CREATE INDEX` format. `SELECT` privilege on any column appearing within index_predicate is required.

constraint_name Explicitly specifies an arbiter constraint by name, rather than inferring a constraint or index.

condition An expression that returns a value of type `boolean`. Only rows for which this expression returns `true` will be updated, although all rows will be locked when the `ON CONFLICT DO UPDATE` action is taken. Note that condition is evaluated last, after a conflict has been identified as a candidate to update.

Note that exclusion constraints are not supported as arbiters with `ON CONFLICT DO UPDATE`. In all cases, only `NOT DEFERRABLE` constraints and unique indexes are supported as arbiters.

`INSERT` with an `ON CONFLICT DO UPDATE` clause is a "deterministic" statement. This means that the command will not be allowed to affect any single existing row more than once; a cardinality violation error will be raised when this situation arises. Rows proposed for insertion should not duplicate each other in terms of attributes constrained by an arbiter index or constraint.

Note that it is currently not supported for the `ON CONFLICT DO UPDATE` clause of an `INSERT` applied to a partitioned table to update the partition key of a conflicting row such that it requires the row be moved to a new partition.

Tip: It is often preferable to use unique index inference rather than naming a constraint directly using `ON CONFLICT ON CONSTRAINT constraint_name`. Inference will continue to work correctly when the underlying index is replaced by another more or less equivalent index in an overlapping way, for example when using `CREATE UNIQUE INDEX ... CONCURRENTLY` before dropping the index being replaced.

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Outputs

On successful completion, an `INSERT` command returns a command tag of the form:

```
INSERT <oid> <count>
```

The count is the number of rows inserted or updated. oid is always `0` (it used to be the OID assigned to the inserted row if count was exactly one and the target table was declared `WITH OIDS` and 0 otherwise, but creating a table `WITH OIDS` is no longer supported).

If the `INSERT` command contains a `RETURNING` clause, the result will be similar to that of a `SELECT` statement containing the columns and values defined in the `RETURNING` list, computed over the row(s) inserted or updated by the command.

Notes

If the specified table is a partitioned table, WarehousePG routes each row to the appropriate partition and inserts into it. If the specified table is a partition, an error will occur if one of the input rows violates the partition constraint.

For a partitioned table, all of the child tables are locked during the `INSERT` operation when the Global Deadlock Detector is not enabled (the default). Only some of the leaf child tables are locked when the Global Deadlock Detector is enabled. For information about the Global Deadlock Detector, see Global Deadlock Detector.

WarehousePG supports a maximum of 127 concurrent `INSERT` transactions into a single append-optimized table.

Examples

Insert a single row into table `films`:

```
INSERT INTO films VALUES
    ('UA502', 'Bananas', 105, '1971-07-13', 'Comedy', '82 minutes');
```

In this example, the `len` column is omitted and therefore it will have the default value:

```
INSERT INTO films (code, title, did, date_prod, kind)
    VALUES ('T_601', 'Yojimbo', 106, '1961-06-16', 'Drama');
```

This example uses the `DEFAULT` clause for the `date_prod` column rather than specifying a value:

```
INSERT INTO films VALUES
    ('UA502', 'Bananas', 105, DEFAULT, 'Comedy', '82 minutes');
INSERT INTO films (code, title, did, date_prod, kind)
    VALUES ('T_601', 'Yojimbo', 106, DEFAULT, 'Drama');
```

To insert a row consisting entirely of default values:

```
INSERT INTO films DEFAULT VALUES;
```

To insert multiple rows using the multirow `VALUES` syntax:

```
INSERT INTO films (code, title, did, date_prod, kind) VALUES
    ('B6717', 'Tampopo', 110, '1985-02-10', 'Comedy'),
    ('HG120', 'The Dinner Game', 140, DEFAULT, 'Comedy');
```

This example inserts some rows into table `films` from a table `tmp_films` with the same column layout as `films`:

```
INSERT INTO films SELECT * FROM tmp_films WHERE date_prod <
'2004-05-07';
```

This example inserts into array columns:

```
-- Create an empty 3x3 gameboard for noughts-and-crosses
INSERT INTO tictactoe (game, board[1:3][1:3])
    VALUES (1, '{{" "," "," "},{" "," "," "},{" "," "," "}}');
-- The subscripts in the above example aren't really needed
INSERT INTO tictactoe (game, board)
    VALUES (2, '{{X," "," "},{" ",O," "},{" ",X," "}}');
```

Insert a single row into table distributors, returning the sequence number generated by the DEFAULT clause:

```
INSERT INTO distributors (did, dname) VALUES (DEFAULT, 'XYZ Widgets')
   RETURNING did;
```

Increment the sales count of the salesperson who manages the account for Acme Corporation, and record the whole updated row along with current time in a log table:

```
WITH upd AS (
  UPDATE employees SET sales_count = sales_count + 1 WHERE id =
    (SELECT sales_person FROM accounts WHERE name = 'Acme Corporation')
    RETURNING *
)
INSERT INTO employees_log SELECT *, current_timestamp FROM upd;
```

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Insert or update new distributors as appropriate. Assumes a unique index has been defined that constrains values appearing in the `did` column. Note that the special `excluded` table is used to reference values originally proposed for insertion:

```
INSERT INTO distributors (did, dname)
    VALUES (5, 'Gizmo Transglobal'), (6, 'Associated Computing, Inc')
    ON CONFLICT (did) DO UPDATE SET dname = EXCLUDED.dname;
```

Insert a distributor, or do nothing for rows proposed for insertion when an existing, excluded row (a row with a matching constrained column or columns after before row insert triggers fire) exists. Example assumes a unique index has been defined that constrains values appearing in the `did` column:

```
INSERT INTO distributors (did, dname) VALUES (7, 'Redline GmbH')
    ON CONFLICT (did) DO NOTHING;
```

Insert or update new distributors as appropriate. Example assumes a unique index has been defined that constrains values appearing in the `did` column. `WHERE` clause is used to limit the rows actually updated (any existing row not updated will still be locked, though):

```
-- Don't update existing distributors based in a certain ZIP code
INSERT INTO distributors AS d (did, dname) VALUES (8, 'Anvil Distribution')
    ON CONFLICT (did) DO UPDATE
    SET dname = EXCLUDED.dname || ' (formerly ' || d.dname || ')'
    WHERE d.zipcode <> '21201';

-- Name a constraint directly in the statement (uses associated
-- index to arbitrate taking the DO NOTHING action)
INSERT INTO distributors (did, dname) VALUES (9, 'Antwerp Design')
    ON CONFLICT ON CONSTRAINT distributors_pkey DO NOTHING;
```

Insert new distributor if possible; otherwise `DO NOTHING`. Example assumes a unique index has been defined that constrains values appearing in the `did` column on a subset of rows where the `is_active` Boolean column evaluates to `true`:

```
-- This statement could infer a partial unique index on "did"
-- with a predicate of "WHERE is_active", but it could also
-- just use a regular unique constraint on "did"
INSERT INTO distributors (did, dname) VALUES (10, 'Conrad International')
    ON CONFLICT (did) WHERE is_active DO NOTHING;
```

Compatibility

`INSERT` conforms to the SQL standard, except that the `RETURNING` clause is a WarehousePG extension, as is the ability to use `WITH` with `INSERT`, and the ability to specify an alternative action with `ON CONFLICT`. Also, the case in which a column name list is omitted, but not all of the columns are filled from the `VALUES` clause or query, is disallowed by the standard.

The SQL standard specifies that `OVERRIDING SYSTEM VALUE` can only be specified if an identity column that is generated always exists. WarehousePG allows the clause in any case and ignores it if it is not applicable.

Possible limitations of the query clause are documented under SELECT.

See Also

SELECT

Parent topic: SQL Commands

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7.1.147 LISTEN

Listens for a notification.

Synopsis

```
LISTEN <channel>
```

Description

`LISTEN` registers the current session as a listener on the notification channel named channel. If the current session is already registered as a listener for this notification channel, nothing is done.

Whenever the command `NOTIFY <channel>` is invoked, either by this session or another one connected to the same database, all of the sessions currently listening on that notification channel are notified, and each will in turn notify its connected client application.

A session can be unregistered for a given notification channel with the `UNLISTEN` command. A session's listen registrations are automatically cleared when the session ends.

The method a client application must use to detect notification events depends on which PostgreSQL application programming interface it uses. With the `libpq` library, the application issues `LISTEN` as an ordinary SQL command, and then must periodically call the function `PQnotifies()` to find out whether any notification events have been received. Other interfaces such as `libpgtcl` provide higher-level methods for handling notify events; indeed, with `libpgtcl` the application programmer should not even issue `LISTEN` or `UNLISTEN` directly. Refer to the documentation for the interface that you are using for more details.

NOTIFY contains a more extensive discussion of the use of `LISTEN` and `NOTIFY`.

Parameters

channel The name of a notification channel (any identifier).

Notes

`LISTEN` takes effect at transaction commit. If `LISTEN` or `UNLISTEN` is run within a transaction that later rolls back, the set of notification channels being listened to is unchanged.

A transaction that has executed `LISTEN` cannot be prepared for two-phase commit.

Examples

Configure and execute a listen/notify sequence from `psql`:

```
LISTEN virtual;
NOTIFY virtual;
Asynchronous notification "virtual" received from server process with PID 8448.
```

Compatibility

There is no `LISTEN` statement in the SQL standard.

See Also

NOTIFY, UNLISTEN

Parent topic: SQL Commands

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7.1.148 LOAD

Loads or reloads a shared library file.

Synopsis

```
LOAD '<filename>'
```

Description

This command loads a shared library file into the WarehousePG server address space. If the file had been loaded previously, it is first unloaded. This command is primarily useful to unload and reload a shared library file that has been changed since the server first loaded it. To make use of the shared library, function(s) in it need to be declared using the `CREATE FUNCTION` command.

The library file name is typically given as just a bare file name, which is sought in the server's library search path (set by `dynamic_library_path`). Alternatively it can be given as a full path name. In either case the platform's standard shared library file name extension may be omitted.

Note that in WarehousePG the shared library file (`.so` file) must reside in the same path location on every host in the WarehousePG cluster (coordinators, segments, and mirrors).

Non-superusers can only apply `LOAD` to library files located in `$libdir/plugins/` — the specified `filename` must begin with exactly that string. You must ensure that only "safe" libraries are installed there.

Parameters

filename The path and file name of a shared library file. This file must exist in the same location on all hosts in your WarehousePG cluster.

Examples

Load a shared library file:

```
LOAD '/usr/edb/whpg7/lib/myfuncs.so';
```

Compatibility

`LOAD` is a WarehousePG extension.

See Also

CREATE FUNCTION

Parent topic: SQL Commands

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7.1.149 LOCK

Locks a table.

Synopsis

```
LOCK [TABLE] [ONLY] name [ * ] [, ...] [IN <lockmode> MODE] [NOWAIT] [COORDINATOR ONLY]
```

where lockmode is one of:

```
    ACCESS SHARE | ROW SHARE | ROW EXCLUSIVE | SHARE UPDATE EXCLUSIVE
  | SHARE | SHARE ROW EXCLUSIVE | EXCLUSIVE | ACCESS EXCLUSIVE
```

Description

`LOCK TABLE` obtains a table-level lock, waiting if necessary for any conflicting locks to be released. If `NOWAIT` is specified, `LOCK TABLE` does not wait to acquire the desired lock: if it cannot be acquired immediately, the command is stopped and an error is emitted. Once obtained, the lock is held for the remainder of the current transaction. There is no `UNLOCK TABLE` command; locks are always released at transaction end.

When acquiring locks automatically for commands that reference tables, WarehousePG always uses the least restrictive lock mode possible. `LOCK TABLE` provides for cases when you might need more restrictive locking. For example, suppose an application runs a transaction at the `READ COMMITTED` isolation level and needs to ensure that data in a table remains stable for the duration of the transaction. To achieve this you could obtain `SHARE` lock mode over the table before querying. This will prevent concurrent data changes and ensure subsequent reads of the table see a stable view of committed data, because `SHARE` lock mode conflicts with the `ROW EXCLUSIVE` lock acquired by writers, and your `LOCK TABLE <name> IN SHARE MODE` statement will wait until any concurrent holders of `ROW EXCLUSIVE` mode locks commit or rolls back. Thus, once you obtain the lock, there are no uncommitted writes outstanding; furthermore none can begin until you release the lock.

To achieve a similar effect when running a transaction at the `REPEATABLE READ` or `SERIALIZABLE` isolation level, you have to run the `LOCK TABLE` statement before running any `SELECT` or data modification statement. A `REPEATABLE READ` or `SERIALIZABLE` transaction's view of data will be frozen when its first `SELECT` or data modification statement begins. A `LOCK TABLE` later in the transaction will still prevent concurrent writes — but it won't ensure that what the transaction reads corresponds to the latest committed values.

If a transaction of this sort is going to change the data in the table, then it should use `SHARE ROW EXCLUSIVE` lock mode instead of `SHARE` mode. This ensures that only one transaction of this type runs at a time. Without this, a deadlock is possible: two transactions might both acquire `SHARE` mode, and then be unable to also acquire `ROW EXCLUSIVE` mode to actually perform their updates. Note that a transaction's own locks never conflict, so a transaction can acquire `ROW EXCLUSIVE` mode when it holds `SHARE` mode — but not if anyone else holds `SHARE` mode. To avoid deadlocks, make sure all transactions acquire locks on the same objects in the same order, and if multiple lock modes are involved for a single object, then transactions should always acquire the most restrictive mode first.

Parameters

name The name (optionally schema-qualified) of an existing table to lock. If `ONLY` is specified, only that table is locked. If `ONLY` is not specified, the table and all its descendant tables (if any) are locked. Optionally, `*` can be specified after the table name to explicitly indicate that descendant tables are included.

If multiple tables are given, tables are locked one-by-one in the order specified in the `LOCK TABLE` command.

lockmode The lock mode specifies which locks this lock conflicts with. If no lock mode is specified, then `ACCESS EXCLUSIVE`, the most restrictive mode, is used. Lock modes are as follows:

```
-   ACCESS SHARE — Conflicts with the `ACCESS EXCLUSIVE` lock mode only. The `SELECT` command acquires a lock of this mode on referenced tables. In general, any
query that only reads a table and does not modify it will acquire this lock mode.
-   ROW SHARE — Conflicts with the `EXCLUSIVE` and `ACCESS EXCLUSIVE` lock modes. The `SELECT FOR SHARE` command automatically acquires a lock of this mode on the
target table\(s\) \(in addition to `ACCESS SHARE` locks on any other tables that are referenced but not selected `FOR SHARE`\).
-   ROW EXCLUSIVE — Conflicts with the `SHARE`, `SHARE ROW EXCLUSIVE`, `EXCLUSIVE`, and `ACCESS EXCLUSIVE` lock modes. The commands `INSERT` and `COPY`
automatically acquire this lock mode on the target table \(in addition to `ACCESS SHARE` locks on any other referenced tables\) See [Note](#lock_note).
-   SHARE UPDATE EXCLUSIVE — Conflicts with the `SHARE UPDATE EXCLUSIVE`, `SHARE`, `SHARE ROW EXCLUSIVE`, `EXCLUSIVE`, and `ACCESS EXCLUSIVE` lock modes. This
mode protects a table against concurrent schema changes and `VACUUM` runs. Acquired by `VACUUM` \(without `FULL`\) on heap tables and `ANALYZE`.
-   SHARE — Conflicts with the `ROW EXCLUSIVE`, `SHARE UPDATE EXCLUSIVE`, `SHARE ROW EXCLUSIVE, EXCLUSIVE`, and `ACCESS EXCLUSIVE` lock modes. This mode protects
a table against concurrent data changes. Acquired automatically by `CREATE INDEX`.
-   SHARE ROW EXCLUSIVE — Conflicts with the `ROW EXCLUSIVE`, `SHARE UPDATE EXCLUSIVE`, `SHARE`, `SHARE ROW EXCLUSIVE`, `EXCLUSIVE`, and `ACCESS EXCLUSIVE` lock
modes. This mode protects a table against concurrent data changes, and is self-exclusive so that only one session can hold it at a time. This lock mode is not
automatically acquired by any WarehousePG command.
-   EXCLUSIVE — Conflicts with the `ROW SHARE`, `ROW EXCLUSIVE`, `SHARE UPDATE EXCLUSIVE`, `SHARE`, `SHARE ROW EXCLUSIVE`, `EXCLUSIVE`, and `ACCESS EXCLUSIVE`
lock modes. This mode allows only concurrent `ACCESS SHARE` locks, i.e., only reads from the table can proceed in parallel with a transaction holding this lock
mode. This lock mode is automatically acquired for `UPDATE`, `SELECT FOR UPDATE`, and `DELETE` in WarehousePG \(which is more restrictive locking than in regular
PostgreSQL\). See [Note](#lock_note).
-   ACCESS EXCLUSIVE — Conflicts with locks of all modes \(`ACCESS SHARE`, `ROW SHARE`, `ROW EXCLUSIVE`, `SHARE UPDATE EXCLUSIVE`, `SHARE`, `SHARE ROW EXCLUSIVE`,
`EXCLUSIVE`, and `ACCESS EXCLUSIVE`\). This mode guarantees that the holder is the only transaction accessing the table in any way. Acquired automatically by the
`ALTER TABLE`, `DROP TABLE`, `TRUNCATE`, `REINDEX`, `CLUSTER`, and `VACUUM FULL` commands. This is the default lock mode for `LOCK TABLE` statements that do not
specify a mode explicitly. This lock is also briefly acquired by `VACUUM` \(without `FULL`\) on append-optimized tables during processing.

> **Note** As the default, WarehousePG acquires an `EXCLUSIVE` lock on tables for `DELETE`, `UPDATE`, and `SELECT FOR UPDATE` operations on heap tables. When the
Global Deadlock Detector is enabled, the lock mode for the operations on heap tables is `ROW EXCLUSIVE`. See [Global Deadlock Detector]
(../../admin_guide/dml.html#topic_gdd).
```

NOWAIT Specifies that `LOCK TABLE` should not wait for any conflicting locks to be released: if the specified lock(s) cannot be acquired immediately without waiting, the transaction is cancelled.

COORDINATOR ONLY Specifies that when a `LOCK TABLE` command is issued, WarehousePG will lock tables on the coordinator only, rather than on the coordinator and all of the segments. This is particularly useful for metadata-only operations.

```
<br/><br/>> **Note** This option is only supported in `ACCESS SHARE MODE`.
```

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Notes

`LOCK TABLE ... IN ACCESS SHARE MODE` requires `SELECT` privileges on the target table. All other forms of `LOCK` require table-level `UPDATE`, `DELETE`, or `TRUNCATE` privileges.

`LOCK TABLE` is useless outside of a transaction block: the lock would be held only to the completion of the `LOCK` statement. Therefore, WarehousePG reports an error if `LOCK` is used outside of a transaction block. Use `BEGIN` and `END` to define a transaction block.

`LOCK TABLE` only deals with table-level locks, and so the mode names involving `ROW` are all misnomers. These mode names should generally be read as indicating the intention of the user to acquire row-level locks within the locked table. Also, `ROW EXCLUSIVE` mode is a shareable table lock. Keep in mind that all the lock modes have identical semantics so far as `LOCK TABLE` is concerned, differing only in the rules about which modes conflict with which. For information on how to acquire an actual row-level lock, see the `FOR UPDATE/FOR SHARE` clause in the SELECT reference documentation.

Examples

Obtain a `SHARE` lock on the `films` table when going to perform inserts into the `films_user_comments` table:

```
BEGIN WORK;
LOCK TABLE films IN SHARE MODE;
SELECT id FROM films
    WHERE name = 'Star Wars: Episode I - The Phantom Menace';
-- Do ROLLBACK if record was not returned
INSERT INTO films_user_comments VALUES
    (_id_, 'GREAT! I was waiting for it for so long!');
COMMIT WORK;
```

Take a `SHARE ROW EXCLUSIVE` lock on a table when performing a delete operation:

```
BEGIN WORK;
LOCK TABLE films IN SHARE ROW EXCLUSIVE MODE;
DELETE FROM films_user_comments WHERE id IN
    (SELECT id FROM films WHERE rating < 5);
DELETE FROM films WHERE rating < 5;
COMMIT WORK;
```

Compatibility

There is no `LOCK TABLE` in the SQL standard, which instead uses `SET TRANSACTION` to specify concurrency levels on transactions. WarehousePG supports that too; see SET TRANSACTION for details.

Except for `ACCESS SHARE`, `ACCESS EXCLUSIVE`, and `SHARE UPDATE EXCLUSIVE` lock modes, the WarehousePG lock modes and the `LOCK TABLE` syntax are compatible with those present in Oracle.

See Also

BEGIN, SET TRANSACTION, SELECT

Parent topic: SQL Commands

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7.1.150 MOVE

Positions a cursor.

Synopsis

```
MOVE [ <forward_direction> [ FROM | IN ] ] <cursor_name>
```

where <forward_direction> can be empty or one of:

```
    NEXT
    FIRST
    LAST
    ABSOLUTE <count>
    RELATIVE <count>
    <count>
    ALL
    FORWARD
    FORWARD <count>
    FORWARD ALL
```

Description

`MOVE` repositions a cursor without retrieving any data. `MOVE` works exactly like the FETCH command, except it only positions the cursor and does not return rows.

> **Note** You cannot `MOVE` a `PARALLEL RETRIEVE CURSOR`.

> **Note** Because WarehousePG does not support scrollable cursors, it is not possible to move a cursor position backwards. You can only move a cursor forward in position using `MOVE`.

The parameters for the `MOVE` command are identical to those of the `FETCH` command; refer to FETCH for details on syntax and usage.

Outputs

On successful completion, a `MOVE` command returns a command tag of the form

```
MOVE <count>
```

The count is the number of rows that a `FETCH` command with the same parameters would have returned (possibly zero).

Examples

Start the transaction:

```
BEGIN;
```

Create a cursor:

```
DECLARE mycursor CURSOR FOR SELECT * FROM films;
```

Skip the first 5 rows in the cursor `mycursor`:

```
MOVE FORWARD 5 IN mycursor;
MOVE 5
```

Fetch the next row after that (row 6):

```
FETCH 1 FROM mycursor;
 code  | title  | did | date_prod  |  kind  |  len
-------+--------+-----+------------+--------+-------
 P_303 | 48 Hrs | 103 | 1982-10-22 | Action | 01:37
(1 row)
```

Close the cursor and end the transaction:

```
CLOSE mycursor;
COMMIT;
```

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Compatibility

There is no `MOVE` statement in the SQL standard.

See Also

DECLARE, FETCH, CLOSE

Parent topic: SQL Commands

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7.1.151 NOTIFY

Generates a notification.

Synopsis

```
NOTIFY <channel> [ , <payload> ]
```

Description

The `NOTIFY` command sends a notification event together with an optional "payload" string to each client application that has previously executed `LISTEN <channel>` for the specified channel name in the current database. Notifications are visible to all users.

`NOTIFY` provides a simple interprocess communication mechanism for a collection of processes accessing the same WarehousePG. A payload string can be sent along with the notification, and higher-level mechanisms for passing structured data can be built by using tables in the database to pass additional data from notifier to listener(s).

The information passed to the client for a notification event includes the notification channel name, the notifying session's server process PID, and the payload string, which is an empty string if it has not been specified.

It is up to the database designer to define the channel names that will be used in a given database and what each one means. Commonly, the channel name is the same as the name of some table in the database, and the notify event essentially means, "I changed this table, take a look at it to see what's new". But no such association is enforced by the `NOTIFY` and `LISTEN` commands. For example, a database designer could use several different channel names to signal different sorts of changes to a single table. Alternatively, the payload string could be used to differentiate various cases.

When `NOTIFY` is used to signal the occurrence of changes to a particular table, a useful programming technique is to put the `NOTIFY` in a statement trigger that is triggered by table updates. In this way, notification happens automatically when the table is changed, and the application programmer cannot accidentally forget to do it.

`NOTIFY` interacts with SQL transactions in some important ways. Firstly, if a `NOTIFY` is executed inside a transaction, the notify events are not delivered until and unless the transaction is committed. This is appropriate, since if the transaction is aborted, all the commands within it have had no effect, including `NOTIFY`. But it can be disconcerting if one is expecting the notification events to be delivered immediately. Secondly, if a listening session receives a notification signal while it is within a transaction, the notification event will not be delivered to its connected client until just after the transaction is completed (either committed or aborted). Again, the reasoning is that if a notification were delivered within a transaction that was later aborted, one would want the notification to be undone somehow — but the server cannot "take back" a notification once it has sent it to the client. So notification events are only delivered between transactions. The upshot of this is that applications using `NOTIFY` for real-time signaling should try to keep their transactions short.

If the same channel name is signaled multiple times from the same transaction with identical payload strings, the database server can decide to deliver a single notification only. On the other hand, WarehousePG will always deliver notifications with distinct payload strings as distinct notifications. Similarly, notifications from different transactions will never get folded into one notification. Except for dropping later instances of duplicate notifications, `NOTIFY` guarantees that notifications from the same transaction get delivered in the order they were sent. It is also guaranteed that messages from different transactions are delivered in the order in which the transactions committed.

It is common for a client that executes `NOTIFY` to be listening on the same notification channel itself. In that case it will get back a notification event, just like all the other listening sessions. Depending on the application logic, this could result in useless work, for example, reading a database table to find the same updates that that session just wrote out. It is possible to avoid such extra work by noticing whether the notifying session's server process PID (supplied in the notification event message) is the same as one's own session's PID (available from `libpq`). When they are the same, the notification event is one's own work bouncing back, and can be ignored.

Parameters

channel The name of a notification channel (any identifier).

payload The "payload" string to be communicated along with the notification. This must be specified as a simple string literal. In the default configuration it must be shorter than 8000 bytes. (If binary data or large amounts of information need to be communicated, it's best to put it in a database table and send the key of the record.)

Notes

There is a queue that holds notifications that have been sent but not yet processed by all listening sessions. If this queue becomes full, transactions calling `NOTIFY` will fail at commit. The queue is quite large (8GB in a standard installation) and should be sufficiently sized for almost every use case. However, no cleanup can take place if a session executes `LISTEN` and then enters a transaction for a very long time. Once the queue is half full you will see warnings in the log file pointing you to the session that is preventing cleanup. In this case you should make sure that this session ends its current transaction so that cleanup can proceed.

The function `pg_notification_queue_usage()` returns the fraction of the queue that is currently occupied by pending notifications.

A transaction that has executed `NOTIFY` cannot be prepared for two-phase commit.

pg_notify

To send a notification you can also use the function `pg_notify(text, text)`. The function takes the channel name as the first argument and the payload as the second. The function is much easier to use than the `NOTIFY` command if you need to work with non-constant channel names and payloads.

Examples

Configure and execute a listen/notify sequence from `psql`:

```
LISTEN virtual;
NOTIFY virtual;
Asynchronous notification "virtual" received from server process with PID 8448.
NOTIFY virtual, 'This is the payload';
Asynchronous notification "virtual" with payload "This is the payload" received from server process with PID 8448.

LISTEN foo;
SELECT pg_notify('fo' || 'o', 'pay' || 'load');
Asynchronous notification "foo" with payload "payload" received from server process with PID 14728.
```

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Compatibility

There is no `NOTIFY` statement in the SQL standard.

See Also

LISTEN, UNLISTEN

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7.1.152 PREPARE

Prepares a statement for execution.

Synopsis

```
PREPARE <name> [ (<data_type> [, ...] ) ] AS <statement>
```

Description

`PREPARE` creates a prepared statement. A prepared statement is a server-side object that can be used to optimize performance. When the `PREPARE` statement is run, the specified statement is parsed, analyzed, and rewritten. When an `EXECUTE` command is subsequently issued, the prepared statement is planned and run. This division of labor avoids repetitive parse analysis work, while allowing the execution plan to depend on the specific parameter values supplied.

Prepared statements can take parameters, values that are substituted into the statement when it is run. When creating the prepared statement, refer to parameters by position, using `$1`, `$2`, etc. You can optionally specify a corresponding list of parameter data types. When a parameter's data type is not specified or is declared as `unknown`, the type is inferred from the context in which the parameter is first referenced (if possible). When running the statement, specify the actual values for these parameters in the EXECUTE statement.

Prepared statements last only for the duration of the current database session. When the session ends, the prepared statement is forgotten, so it must be recreated before being used again. This also means that a single prepared statement cannot be used by multiple simultaneous database clients; however, each client can create their own prepared statement to use. You can manually clean up a prepared statement using the DEALLOCATE command.

Prepared statements have the largest performance advantage when a single session is being used to run a large number of similar statements. The performance difference will be particularly significant if the statements are complex to plan or rewrite, for example, if the query involves a join of many tables or requires the application of several rules. If the statement is relatively simple to plan and rewrite but relatively expensive to run, the performance advantage of prepared statements will be less noticeable.

Parameters

name An arbitrary name given to this particular prepared statement. It must be unique within a single session and is subsequently used to run or deallocate a previously prepared statement.

data_type The data type of a parameter to the prepared statement. If the data type of a particular parameter is unspecified or is specified as `unknown`, it will be inferred from the context in which the parameter is first referenced. To refer to the parameters in the prepared statement itself, use `$1`, `$2`, etc.

statement Any `SELECT`, `INSERT`, `UPDATE`, `DELETE`, or `VALUES` statement.

Notes

A prepared statement can be run with either a *generic plan* or a *custom plan*. A generic plan is the same across all executions, while a custom plan is generated for a specific execution using the parameter values given in that call. Use of a generic plan avoids planning overhead, but in some situations a custom plan will be much more efficient to run because the planner can make use of knowledge of the parameter values. If the prepared statement has no parameters, a generic plan is always used.

By default (with the default value, `auto`, for the server configuration parameter plan_cache_mode), the server automatically chooses whether to use a generic or custom plan for a prepared statement that has parameters. The current rule for this is that the first five executions are done with custom plans and then WarehousePG calculates the average estimated cost of those plans. Then a generic plan is created and its estimated cost is compared to the average custom-plan cost. Subsequent executions use the generic plan if its cost is not so much higher than the average custom-plan cost as to make repeated replanning seem preferable.

You can override this heuristic, forcing the server to use either generic or custom plans, by setting `plan_cache_mode` to `force_generic_plan` or `force_custom_plan` respectively. This setting is primarily useful if the generic plan's cost estimate is badly off for some reason, allowing it to be chosen even though its actual cost is much more than that of a custom plan.

To examine the query plan WarehousePG is using for a prepared statement, use EXPLAIN, for example:

```
EXPLAIN EXECUTE <name>(<parameter_values>);
```

If a generic plan is in use, it will contain parameter symbols `$n`, while a custom plan will have the supplied parameter values substituted into it.

For more information on query planning and the statistics collected by WarehousePG for that purpose, see theANALYZE documentation.

Although the main point of a prepared statement is to avoid repeated parse analysis and planning of the statement, WarehousePG will force re-analysis and re-planning of the statement before using it whenever database objects used in the statement have undergone definitional (DDL) changes since the previous use of the prepared statement. Also, if the value of search_path changes from one use to the next, the statement will be re-parsed using the new `search_path`. These rules make use of a prepared statement semantically almost equivalent to re-submitting the same query text over and over, but with a performance benefit if no object definitions are changed, especially if the best plan remains the same across uses. An example of a case where the semantic equivalence is not perfect is that if the statement refers to a table by an unqualified name, and then a new table of the same name is created in a schema appearing earlier in the `search_path`, no automatic re-parse will occur since no object used in the statement changed. However, if some other change forces a re-parse, the new table will be referenced in subsequent uses.

You can see all prepared statements available in the session by querying the pg_prepared_statements system view.

Examples

Create a prepared statement for an `INSERT` statement, and then run it:

```
PREPARE fooplan (int, text, bool, numeric) AS
    INSERT INTO foo VALUES($1, $2, $3, $4);
EXECUTE fooplan(1, 'Hunter Valley', 't', 200.00);
```

Create a prepared statement for a `SELECT` statement, and then run it. Note that the data type of the second parameter is not specified, so it is inferred from the context in which `$2` is used:

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```
PREPARE usrrptplan (int) AS
    SELECT * FROM users u, logs l WHERE u.usrid=$1 AND u.usrid=l.usrid
    AND l.date = $2;
EXECUTE usrrptplan(1, current_date);
```

Compatibility

The SQL standard includes a `PREPARE` statement, but it can only be used in embedded SQL, and it uses a different syntax.

See Also

EXECUTE, DEALLOCATE

Parent topic: SQL Commands

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7.1.153 REASSIGN OWNED

Changes the ownership of database objects owned by a database role.

Synopsis

```
REASSIGN OWNED BY { <old_role> | CURRENT_USER | SESSION_USER } [, ...]
               TO { <new_role> | CURRENT_USER | SESSION_USER }
```

Description

`REASSIGN OWNED` changes the ownership of database objects owned by any of the old_roles to new_role.

Parameters

old_role The name of a role. The ownership of all the objects in the current database, and of all shared objects (databases, tablespaces), owned by this role will be reassigned to new_role.

new_role The name of the role that will be made the new owner of the affected objects.

Notes

`REASSIGN OWNED` is often used to prepare for the removal of one or more roles. Because `REASSIGN OWNED` does not affect objects in other databases, it is usually necessary to run this command in each database that contains objects owned by a role that is to be removed.

`REASSIGN OWNED` requires privileges on both the source role(s) and the target role.

The DROP OWNED command is an alternative that simply drops all of the database objects owned by one or more roles.

The `REASSIGN OWNED` command does not affect any privileges granted to the old_roles on objects that are not owned by them. Likewise, it does not affect default privileges created with `ALTER DEFAULT PRIVILEGES`. Use `DROP OWNED` to revoke such privileges.

Examples

Reassign any database objects owned by the role named `sally` and `bob` to `admin`:

```
REASSIGN OWNED BY sally, bob TO admin;
```

Compatibility

The `REASSIGN OWNED` command is a WarehousePG extension.

See Also

DROP OWNED, DROP ROLE, ALTER DATABASE

Parent topic: SQL Commands

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7.1.154 REFRESH MATERIALIZED VIEW

Replaces the contents of a materialized view.

Synopsis

```
REFRESH MATERIALIZED VIEW [ CONCURRENTLY ] <name>
    [ WITH [ NO ] DATA ]
```

Description

`REFRESH MATERIALIZED VIEW` completely replaces the contents of a materialized view. The old contents are discarded. To run this command you must be the owner of the materialized view. If `WITH DATA` is specified (or defaults), the backing query is executed to provide the new data, and the materialized view is left in a scannable state. If `WITH NO DATA` is specified, no new data is generated, and the materialized view is left in an unscannable state.

You may not specify `CONCURRENTLY` and `WITH NO DATA` together.

Parameters

CONCURRENTLY Refresh the materialized view without locking out concurrent selects on the materialized view. Without this option, a refresh that affects a lot of rows tends to use fewer resources and completes more quickly, but could block other connections which are trying to read from the materialized view. This option might be faster in cases where a small number of rows are affected. This option is only allowed if there is at least one `UNIQUE` index on the materialized view which uses only column names and includes all rows; that is, it must not index on any expressions nor include a `WHERE` clause. You can not use this option when the materialized view is not already populated. Even with this option, only one `REFRESH` at a time may run against any one materialized view.

name The name (optionally schema-qualified) of the materialized view to refresh.

WITH [NO] DATA `WITH DATA` is the default and specifies that the materialized view query is run to provide new data, and the materialized view is left in a scannable state. If `WITH NO DATA` is specified, no new data is generated and the materialized view is left in an unscannable state.

Notes

If there is an `ORDER BY` clause in the materialized view's defining query, the original contents of the materialized view will be ordered that way; but `REFRESH MATERIALIZED VIEW` does not guarantee to preserve that ordering.

Examples

This command replaces the contents of the materialized view `order_summary` using the query from the materialized view's definition, and leaves it in a scannable state.

```
REFRESH MATERIALIZED VIEW order_summary;
```

This command frees storage associated with the materialized view `annual_statistics_basis` and leaves it in an unscannable state.

```
REFRESH MATERIALIZED VIEW annual_statistics_basis WITH NO DATA;
```

Compatibility

`REFRESH MATERIALIZED VIEW` is a WarehousePG extension of the SQL standard.

See Also

ALTER MATERIALIZED VIEW, CREATE MATERIALIZED VIEW, DROP MATERIALIZED VIEW

Parent topic: SQL Commands

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7.1.155 REINDEX

Rebuilds indexes.

Synopsis

```
REINDEX [ (VERBOSE) ] { INDEX | TABLE | SCHEMA | DATABASE | SYSTEM } <name>
```

Description

`REINDEX` rebuilds an index using the data stored in the index's table, replacing the old copy of the index. There are several scenarios in which to use `REINDEX`:

- An index has become corrupted, and no longer contains valid data. Although in theory this should never happen, in practice indexes can become corrupted due to software bugs or hardware failures. `REINDEX` provides a recovery method.
- An index has become bloated, that is, it contains many empty or nearly-empty pages. This can occur with B-tree indexes in WarehousePG under certain uncommon access patterns. `REINDEX` provides a way to reduce the space consumption of the index by writing a new version of the index without the dead pages.
- You have altered a storage parameter (such as `fillfactor`) for an index, and wish to ensure that the change has taken full effect.

Parameters

INDEX Recreate the specified index.

TABLE Recreate all indexes of the specified table. If the table has a secondary "TOAST" table, that is reindexed as well.

SCHEMA Recreate all indexes of the specified schema. If a table of this schema has a secondary "TOAST" table, that is reindexed as well. Indexes on shared system catalogs are also processed. You cannot run this form of `REINDEX` inside a transaction block.

DATABASE Recreate all indexes within the current database. Indexes on shared system catalogs are also processed. This form of `REINDEX` cannot be run inside a transaction block.

SYSTEM Recreate all indexes on system catalogs within the current database. Indexes on shared system catalogs are included. Indexes on user tables are not processed. This form of `REINDEX` cannot be run inside a transaction block.

name The name of the specific index, table, or database to be reindexed. Index and table names may be schema-qualified. Presently, `REINDEX DATABASE` and `REINDEX SYSTEM` can only reindex the current database, so their parameter must match the current database's name.

VERBOSE Prints a progress report as each index is reindexed.

Notes

WarehousePG does not support concurrently recreating indexes (`CONCURRENTLY` keyword is not supported).

`REINDEX` causes locking of system catalog tables, which could affect currently running queries. To avoid disrupting ongoing business operations, schedule the `REINDEX` operation during a period of low activity.

`REINDEX` is similar to a drop and recreate of the index in that the index contents are rebuilt from scratch. However, the locking considerations are rather different. `REINDEX` locks out writes but not reads of the index's parent table. It also takes an `ACCESS EXCLUSIVE` lock on the specific index being processed, which will block reads that attempt to use that index. In contrast, `DROP INDEX` momentarily takes an `ACCESS EXCLUSIVE` lock on the parent table, blocking both writes and reads. The subsequent `CREATE INDEX` locks out writes but not reads; since the index is not there, no read will attempt to use it, meaning that there will be no blocking but reads may be forced into expensive sequential scans.

Reindexing a single index or table requires being the owner of that index or table. Reindexing a schema or database requires being the owner of the schema or database. Note that it is therefore sometimes possible for non-superusers to rebuild indexes of tables owned by other users. However, as a special exception, when a non-superuser issues `REINDEX DATABASE`, `REINDEX SCHEMA` or `REINDEX SYSTEM`, WarehousePG skips indexes on shared catalogs unless the user owns the catalog (which typically won't be the case). Of course, superusers can always reindex anything.

REINDEX`does not update the` reltuples `and` relpages `statistics for the index. To update those statistics, run` ANALYZE` on the table after reindexing.

Examples

Rebuild a single index:

```
REINDEX INDEX my_index;
```

Rebuild all the indexes on the table `my_table`:

```
REINDEX TABLE my_table;
```

Rebuild all indexes in a particular database, without trusting the system indexes to be valid already:

```
$ export PGOPTIONS="-P"
$ psql broken_db
...
broken_db=> REINDEX DATABASE broken_db;
broken_db=> \q
```

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Compatibility

There is no `REINDEX` command in the SQL standard.

See Also

CREATE INDEX, DROP INDEX, VACUUM, reindexdb

Parent topic: SQL Commands

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7.1.156 RELEASE SAVEPOINT

Destroys a previously defined savepoint.

Synopsis

```
RELEASE [SAVEPOINT] <savepoint_name>
```

Description

`RELEASE SAVEPOINT` destroys a savepoint previously defined in the current transaction.

Destroying a savepoint makes it unavailable as a rollback point, but it has no other user visible behavior. It does not undo the effects of commands run after the savepoint was established. (To do that, see ROLLBACK TO SAVEPOINT.) Destroying a savepoint when it is no longer needed may allow the system to reclaim some resources earlier than transaction end.

`RELEASE SAVEPOINT` also destroys all savepoints that were established *after* the named savepoint was established.

Parameters

savepoint_name The name of the savepoint to destroy.

Notes

Specifying a savepoint name that was not previously defined is an error.

It is not possible to release a savepoint when the transaction is in an aborted state.

If multiple savepoints have the same name, WarehousePG releases only the most recently defined unreleased savepoint. Repeated commands release progressively older savepoints.

Examples

To establish and later destroy a savepoint:

```
BEGIN;
    INSERT INTO table1 VALUES (3);
    SAVEPOINT my_savepoint;
    INSERT INTO table1 VALUES (4);
    RELEASE SAVEPOINT my_savepoint;
COMMIT;
```

The above transaction inserts both 3 and 4.

Compatibility

This command conforms to the SQL standard. The standard specifies that the key word `SAVEPOINT` is mandatory, but WarehousePG allows it to be omitted.

See Also

BEGIN, COMMIT, ROLLBACK, ROLLBACK TO SAVEPOINT, SAVEPOINT

Parent topic: SQL Commands

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7.1.157 RESET

Restores the value of a run-time system configuration parameter to the default value.

Synopsis

```
RESET <configuration_parameter>

RESET ALL
```

Description

`RESET` restores system configuration parameters to their default values. `RESET` is an equivalent command for

```
SET <configuration_parameter> TO DEFAULT
```

Refer to SET for details.

The default value is defined as the value that the parameter would have had, had no `SET` ever been issued for it in the current session. The actual source of this value might be a compiled-in default, the coordinator `postgresql.conf` configuration file, command-line options, or per-database or per-user default settings. This is subtly different from defining it as "the value that the parameter had at session start", because if the value came from the configuration file, it will be reset to whatever is specified by the configuration file now. See Server Configuration Parameters for more information.

The transactional behavior of `RESET` is the same as `SET`: its effects will be undone by transaction rollback.

Parameters

configuration_parameter The name of a settable run-time system configuration parameter. See Server Configuration Parameters for details.

ALL Resets all settable run-time configuration parameters to their default values.

Examples

Set the `statement_mem` configuration parameter to its default value:

```
RESET statement_mem;
```

Compatibility

`RESET` is a WarehousePG extension.

See Also

SET, SHOW

Parent topic: SQL Commands

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7.1.158 RETRIEVE

Retrieves rows from a query using a parallel retrieve cursor.

Synopsis

```
RETRIEVE { <count> | ALL } FROM ENDPOINT <endpoint_name>
```

Description

`RETRIEVE` retrieves rows using a previously-created parallel retrieve cursor. You retrieve the rows in individual retrieve sessions, separate direct connections to individual segment endpoints that will serve the results for each individual segment. When you initiate a retrieve session, you must specify gp_retrieve_conn=true on the connection request. Because a retrieve session is independent of the parallel retrieve cursors or their corresponding endpoints, you can `RETRIEVE` from multiple endpoints in the same retrieve session.

A parallel retrieve cursor has an associated position, which is used by `RETRIEVE`. The cursor position can be before the first row of the query result, on any particular row of the result, or after the last row of the result.

> **Note** Because WarehousePG does not support scrollable cursors, the `RETRIEVE` command moves a parallel retrieve cursor only forward in position.

When it is created, a parallel retrieve cursor is positioned before the first row. After retrieving some rows, the cursor is positioned on the row most recently retrieved.

If `RETRIEVE` runs off the end of the available rows then the cursor is left positioned after the last row.

`RETRIEVE ALL` always leaves the parallel retrieve cursor positioned after the last row.

Parameters

count Retrieve the next count number of rows. count must be a positive number.

ALL Retrieve all remaining rows.

endpoint_name The name of the endpoint from which to retrieve the rows.

Outputs

On successful completion, a `RETRIEVE` command returns the fetched rows (possibly empty) and a count of the number of rows fetched (possibly zero).

Notes

Use `DECLARE ... PARALLEL RETRIEVE CURSOR` to define a parallel retrieve cursor.

Parallel retrieve cursors do not support `FETCH` or `MOVE` operations.

Examples

Start the transaction:

```
BEGIN;
```

Create a parallel retrieve cursor:

```
DECLARE mycursor PARALLEL RETRIEVE CURSOR FOR SELECT * FROM films;
```

List the cursor endpoints:

```
SELECT * FROM gp_endpoints WHERE cursorname='mycursor';
```

Note the hostname, port, auth_token, and name associated with each endpoint.

In another terminal window, initiate a retrieve session using a hostname, port, and auth_token returned from the previous query. For example:

```
PGPASSWORD=d3825fc07e56bee5fcd2b1d0b600c85e PGOPTIONS='-c gp_retrieve_conn=true' psql -d testdb -h sdw3 -p 6001;
```

Fetch all rows from an endpoint (for example, the endpoint named `prc10000001100000005`):

```
RETRIEVE ALL FROM ENDPOINT prc10000001100000005;
```

Exit the retrieve session.

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```
\q
```

Back in the original session, close the cursor and end the transaction:

```
CLOSE mycursor;
COMMIT;
```

Compatibility

`RETRIEVE` is a WarehousePG extension. The SQL standard makes no provisions for parallel retrieve cursors.

See Also

DECLARE, CLOSE

Parent topic: SQL Commands

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7.1.159 REVOKE

Removes access privileges.

Synopsis

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```
REVOKE [GRANT OPTION FOR]
       { {SELECT | INSERT | UPDATE | DELETE | REFERENCES | TRIGGER | TRUNCATE }
       [, ...] | ALL [PRIVILEGES] }
       ON { { [TABLE] [[[ONLY] <table_name> [, ...]] [, ...]] }
          | ALL TABLES IN SCHEMA schema_name [, ...] }
       FROM <role_specification> [, ...]
       [CASCADE | RESTRICT]

REVOKE [ GRANT OPTION FOR ]
       { { SELECT | INSERT | UPDATE | REFERENCES } ( <column_name> [, ...] )
       [, ...] | ALL [ PRIVILEGES ] ( <column_name> [, ...] ) }
       ON { [ [TABLE] [[[ONLY] <table_name> [, ...]] [, ...]] }
       FROM <role_specification> [, ...]
       [ CASCADE | RESTRICT ]

REVOKE [GRANT OPTION FOR] { {USAGE | SELECT | UPDATE} [,...]
       | ALL [PRIVILEGES] }
       ON { SEQUENCE <sequence_name> [, ...]
            | ALL SEQUENCES IN SCHEMA schema_name [, ...] }
       FROM <role_specification> [, ...]
       [CASCADE | RESTRICT]

REVOKE [GRANT OPTION FOR]
       { {CREATE | CONNECT | TEMPORARY | TEMP} [, ...] | ALL [PRIVILEGES] }
       ON DATABASE <database_name> [, ...]
       FROM <role_specification> [, ...]
       [CASCADE | RESTRICT]

REVOKE [ GRANT OPTION FOR ]
       { USAGE | ALL [ PRIVILEGES ] }
       ON DOMAIN <domain_name> [, ...]
       FROM <role_specification> [, ...]
       [ CASCADE | RESTRICT ]

REVOKE [ GRANT OPTION FOR ]
       { USAGE | ALL [ PRIVILEGES ] }
       ON FOREIGN DATA WRAPPER <fdw_name> [, ...]
       FROM <role_specification> [, ...]
       [ CASCADE | RESTRICT ]

REVOKE [ GRANT OPTION FOR ]
       { USAGE | ALL [ PRIVILEGES ] }
       ON FOREIGN SERVER <server_name> [, ...]
       FROM <role_specification> [, ...]
       [ CASCADE | RESTRICT ]

REVOKE [GRANT OPTION FOR] {EXECUTE | ALL [PRIVILEGES]}
       ON { { FUNCTION | PROCEDURE | ROUTINE }  <funcname> [( [[<argmode>] [<argname>] <argtype> [, ...]] )] [, ...]
            | ALL { FUNCTIONS | PROCEDURES | ROUTINES } IN SCHEMA schema_name [, ...] }
       FROM <role_specification> [, ...]
       [CASCADE | RESTRICT]

REVOKE [GRANT OPTION FOR] {USAGE | ALL [PRIVILEGES]}
       ON LANGUAGE <lang_name> [, ...]
       FROM <role_specification> [, ...]
       [ CASCADE | RESTRICT ]

REVOKE [GRANT OPTION FOR] { {CREATE | USAGE} [, ...] | ALL [PRIVILEGES] }
       ON SCHEMA <schema_name> [, ...]
       FROM <role_specification> [, ...]
       [CASCADE | RESTRICT]

REVOKE [GRANT OPTION FOR] { CREATE | ALL [PRIVILEGES] }
       ON TABLESPACE <tablespace_name> [, ...]
       FROM <role_specification> [, ...]
       [CASCADE | RESTRICT]

REVOKE [ GRANT OPTION FOR ]
       { USAGE | ALL [ PRIVILEGES ] }
       ON TYPE <type_name> [, ...]
       FROM <role_specification> [, ...]
       [ CASCADE | RESTRICT ]

REVOKE [ADMIN OPTION FOR] <role_name> [, ...]
       FROM [ GROUP ] <role_specification> [, ...]
       [GRANTED BY <role_specification> ]
       [CASCADE | RESTRICT]

where <role_specification> can be:

    [ GROUP ] <role_name>
  | PUBLIC
  | CURRENT_USER
  | SESSION_USER
```

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Description

`REVOKE` command revokes previously granted privileges from one or more roles. The key word `PUBLIC` refers to the implicitly defined group of all roles.

See the description of the GRANT command for the meaning of the privilege types.

Note that any particular role will have the sum of privileges granted directly to it, privileges granted to any role it is presently a member of, and privileges granted to `PUBLIC`. Thus, for example, revoking `SELECT` privilege from `PUBLIC` does not necessarily mean that all roles have lost `SELECT` privilege on the object: those who have it granted directly or via another role will still have it. Similarly, revoking `SELECT` from a user might not prevent that user from using `SELECT` if `PUBLIC` or another membership role still has `SELECT` rights.

If `GRANT OPTION FOR` is specified, only the grant option for the privilege is revoked, not the privilege itself. Otherwise, both the privilege and the grant option are revoked.

If a role holds a privilege with grant option and has granted it to other roles then the privileges held by those other roles are called dependent privileges. If the privilege or the grant option held by the first role is being revoked and dependent privileges exist, those dependent privileges are also revoked if `CASCADE` is specified, else the revoke action will fail. This recursive revocation only affects privileges that were granted through a chain of roles that is traceable to the role that is the subject of this `REVOKE` command. Thus, the affected roles may effectively keep the privilege if it was also granted through other roles.

When you revoke privileges on a table, WarehousePG revokes the corresponding column privileges (if any) on each column of the table, as well. On the other hand, if a role has been granted privileges on a table, then revoking the same privileges from individual columns will have no effect.

By default, when you revoke privileges on a partitioned table, WarehousePG recurses the operation to its child tables. To direct WarehousePG to perform the `REVOKE` on the partitioned table only, specify the `ONLY <table_name>` clause.

When revoking membership in a role, `GRANT OPTION` is instead called `ADMIN OPTION`, but the behavior is similar. This form of the command also allows a `GRANTED BY` option, but that option is currently ignored (except for checking the existence of the named role). Note also that this form of the command does not allow the noise word `GROUP` in role_specification.

Parameters

See GRANT.

Notes

A user may revoke only those privileges directly granted by that user. If, for example, user A grants a privilege with grant option to user B, and user B has in turn granted it to user C, then user A cannot revoke the privilege directly from C. Instead, user A could revoke the grant option from user B and use the `CASCADE` option so that the privilege is in turn revoked from user C. For another example, if both A and B grant the same privilege to C, A can revoke their own grant but not B's grant, so C effectively still has the privilege.

When a non-owner of an object attempts to `REVOKE` privileges on the object, the command fails outright if the user has no privileges whatsoever on the object. As long as some privilege is available, the command proceeds, but it will revoke only those privileges for which the user has grant options. The `REVOKE ALL PRIVILEGES` forms issue a warning message if no grant options are held, while the other forms issue a warning if grant options for any of the privileges specifically named in the command are not held. (In principle these statements apply to the object owner as well, but since WarehousePG always treats the owner as holding all grant options, the cases can never occur.)

If a superuser chooses to issue a `GRANT` or `REVOKE` command, WarehousePG performs the command as though it were issued by the owner of the affected object. Since all privileges ultimately come from the object owner (possibly indirectly via chains of grant options), it is possible for a superuser to revoke all privileges, but this might require use of `CASCADE` as stated above.

`REVOKE` may also be invoked by a role that is not the owner of the affected object, but is a member of the role that owns the object, or is a member of a role that holds privileges `WITH GRANT OPTION` on the object. In this case, WarehousePG performs the command as though it were issued by the containing role that actually owns the object or holds the privileges `WITH GRANT OPTION`. For example, if table `t1` is owned by role `g1`, of which role `u1` is a member, then `u1` can revoke privileges on `t1` that are recorded as being granted by `g1`. This includes grants made by `u1` as well as by other members of role `g1`.

If the role that runs `REVOKE` holds privileges indirectly via more than one role membership path, it is unspecified which containing role will be used to perform the command. In such cases it is best practice to use `SET ROLE` to become the specific role as which you want to do the `REVOKE`. Failure to do so may lead to revoking privileges other than the ones you intended, or not revoking any privileges at all.

Use `psql`'s `\dp` meta-command to obtain information about existing privileges for tables and columns. There are other `\d` meta-commands that you can use to display the privileges of non-table objects.

Examples

Revoke insert privilege for the public on table `films`:

```
REVOKE INSERT ON films FROM PUBLIC;
```

Revoke all privileges from user `manuel` on view `kinds`. Note that this actually means revoke all privileges that the current role granted (if not a superuser).

```
REVOKE ALL PRIVILEGES ON kinds FROM manuel;
```

Revoke membership in role `admins` from user `joe`:

```
REVOKE admins FROM joe;
```

Compatibility

The compatibility notes of the GRANT command also apply to `REVOKE`.

Either `RESTRICT` or `CASCADE` is required according to the standard, but WarehousePG assumes `RESTRICT` by default.

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See Also

ALTER DEFAULT PRIVILEGES, GRANT

Parent topic: SQL Commands

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7.1.160 ROLLBACK

Stops the current transaction.

Synopsis

```
ROLLBACK [WORK | TRANSACTION] [AND [NO] CHAIN]
```

Description

`ROLLBACK` rolls back the current transaction and causes all the updates made by the transaction to be discarded.

Parameters

WORK TRANSACTION Optional key words. They have no effect.

AND CHAIN If `AND CHAIN` is specified, a new transaction is immediately started with the same transaction characteristics (see SET TRANSACTION) as the just finished one. Otherwise, no new transaction is started.

Notes

Use COMMIT to successfully end the current transaction.

Issuing `ROLLBACK` when not inside a transaction block emits a warning and otherwise has no effect. `ROLLBACK AND CHAIN` outside of a transaction block is an error.

Examples

To discard all changes made in the current transaction:

```
ROLLBACK;
```

Compatibility

The command `ROLLBACK` conforms to the SQL standard. The form `ROLLBACK TRANSACTION` is a WarehousePG extension.

See Also

BEGIN, COMMIT, ROLLBACK TO SAVEPOINT, SAVEPOINT

Parent topic: SQL Commands

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7.1.161 ROLLBACK TO SAVEPOINT

Rolls back the current transaction to a savepoint.

Synopsis

```
ROLLBACK [ WORK | TRANSACTION ] TO [ SAVEPOINT ] <savepoint_name>
```

Description

This command rolls back all commands that were run after the savepoint was established. The savepoint remains valid and can be rolled back to again later, if needed.

`ROLLBACK TO SAVEPOINT` implicitly destroys all savepoints that were established after the named savepoint.

Parameters

WORK TRANSACTION Optional key words. They have no effect.

savepoint_name The name of the savepoint to roll back to.

Notes

Use RELEASE SAVEPOINT to destroy a savepoint without discarding the effects of commands run after it was established.

Specifying a savepoint name that has not been established is an error.

Cursors have somewhat non-transactional behavior with respect to savepoints. Any cursor that is opened inside a savepoint will be closed when the savepoint is rolled back. If a previously opened cursor is affected by a `FETCH` command inside a savepoint that is later rolled back, the cursor remains at the position that `FETCH` left it pointing to (that is, cursor motion caused by `FETCH` is not rolled back). Closing a cursor is not undone by rolling back, either. However, other side-effects caused by the cursor's query (such as side-effects of volatile functions called by the query) *are* rolled back if they occur during a savepoint that is later rolled back. A cursor whose execution causes a transaction to end prematurely is put in a cannot-execute state, so while the transaction can be restored using `ROLLBACK TO SAVEPOINT`, the cursor can no longer be used.

Examples

To undo the effects of the commands run after `my_savepoint` was established:

```
ROLLBACK TO SAVEPOINT my_savepoint;
```

Cursor positions are not affected by a savepoint rollback:

```
BEGIN;
DECLARE foo CURSOR FOR SELECT 1 UNION SELECT 2;
SAVEPOINT foo;
FETCH 1 FROM foo;
column
----------
        1

ROLLBACK TO SAVEPOINT foo;
FETCH 1 FROM foo;
column
----------
        2

COMMIT;
```

Compatibility

The SQL standard specifies that the key word `SAVEPOINT` is mandatory, but WarehousePG (and Oracle) allow it to be omitted. SQL allows only `WORK`, not `TRANSACTION`, as a noise word after `ROLLBACK`. Also, SQL has an optional clause `AND [NO] CHAIN` which is not currently supported by WarehousePG. Otherwise, this command conforms to the SQL standard.

See Also

BEGIN, COMMIT, RELEASE SAVEPOINT, ROLLBACK, SAVEPOINT

Parent topic: SQL Commands

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7.1.162 SAVEPOINT

Defines a new savepoint within the current transaction.

Synopsis

```
SAVEPOINT <savepoint_name>
```

Description

`SAVEPOINT` establishes a new savepoint within the current transaction.

A savepoint is a special mark inside a transaction that allows all commands that are run after it was established to be rolled back, restoring the transaction state to what it was at the time of the savepoint.

Parameters

savepoint_name The name of the new savepoint. If savepoints with the same name already exist, they are inaccessible until newer identically-named savepoints are released.

Notes

Use ROLLBACK TO SAVEPOINT to rollback to a savepoint. Use RELEASE SAVEPOINT to destroy a savepoint, keeping the effects of commands run after it was established.

Savepoints can be established only inside a transaction block. You can define multiple savepoints within a transaction.

Examples

To establish a savepoint and later undo the effects of all commands run after it was established:

```
BEGIN;
    INSERT INTO table1 VALUES (1);
    SAVEPOINT my_savepoint;
    INSERT INTO table1 VALUES (2);
    ROLLBACK TO SAVEPOINT my_savepoint;
    INSERT INTO table1 VALUES (3);
COMMIT;
```

The above transaction inserts the values 1 and 3, but not 2.

To establish and later destroy a savepoint:

```
BEGIN;
    INSERT INTO table1 VALUES (3);
    SAVEPOINT my_savepoint;
    INSERT INTO table1 VALUES (4);
    RELEASE SAVEPOINT my_savepoint;
COMMIT;
```

The above transaction inserts both 3 and 4.

To use a single savepoint name:

```
BEGIN;
    INSERT INTO table1 VALUES
(1);
    SAVEPOINT my_savepoint;
    INSERT INTO table1 VALUES
(2);
    SAVEPOINT my_savepoint;
    INSERT INTO table1 VALUES
(3);

    -- rollback to the second
savepoint
    ROLLBACK TO SAVEPOINT my_savepoint;
    SELECT * FROM table1;               -- shows rows 1 and
2

    -- release the second
savepoint
    RELEASE SAVEPOINT my_savepoint;

    -- rollback to the first
savepoint
    ROLLBACK TO SAVEPOINT my_savepoint;
    SELECT * FROM table1;               -- shows only row
1
COMMIT;
```

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The above transaction shows row 3 being rolled back first, then row 2.

Compatibility

SQL requires a savepoint to be destroyed automatically when another savepoint with the same name is established. In WarehousePG, the old savepoint is kept, though only the more recent one is used when rolling back or releasing. (Releasing the newer savepoint will cause the older one to again become accessible to ROLLBACK TO SAVEPOINT and RELEASE SAVEPOINT.) Otherwise, `SAVEPOINT` is fully SQL conforming.

See Also

BEGIN, COMMIT, RELEASE SAVEPOINT, ROLLBACK, ROLLBACK TO SAVEPOINT

Parent topic: SQL Commands

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7.1.163 SELECT

Retrieves rows from a table or view.

Synopsis

```
[ WITH [ RECURSIVE ] <with_query> [, ...] ]
SELECT [ALL | DISTINCT [ON (<expression> [, ...])]]
  [* | <expression> [[AS] <output_name>] [, ...]]
  [FROM <from_item> [, ...]]
  [WHERE <condition>]
  [GROUP BY <grouping_element> [, ...]]
  [HAVING <condition> [, ...]]
  [WINDOW <window_name> AS (<window_definition>) [, ...] ]
  [{UNION | INTERSECT | EXCEPT} [ALL | DISTINCT] <select>]
  [ORDER BY <expression> [ASC | DESC | USING <operator>] [NULLS {FIRST | LAST}] [, ...]]
  [LIMIT {<count> | ALL}]
  [OFFSET <start> [ ROW | ROWS ] ]
  [FETCH { FIRST | NEXT } [ <count> ] { ROW | ROWS } ONLY]
  [FOR {UPDATE | NO KEY UPDATE | SHARE | KEY SHARE} [OF <table_name> [, ...]] [NOWAIT | SKIP LOCKED ] [...]]

where <from_item> can be one of:

  [ONLY] <table_name> [ * ] [ [ AS ] <alias> [ ( <column_alias> [, ...] ) ] ]
      [ TABLESAMPLE <sampling_method> ( <argument> [, ...] ) [ REPEATABLE ( <seed> ) ] ]
  [LATERAL] ( <select> ) [ AS ] <alias> [( <column_alias> [, ...] ) ]
  <with_query_name> [ [ AS ] <alias> [ ( <column_alias> [, ...] ) ] ]
  [LATERAL] <function_name> ( [ <argument> [, ...] ] )
      [ WITH ORDINALITY ] [ [ AS ] <alias> [ ( <column_alias> [, ...] ) ] ]
  [LATERAL] <function_name> ( [ <argument> [, ...] ] ) [ AS ] <alias> ( <column_definition> [, ...] )
  [LATERAL] <function_name> ( [ <argument> [, ...] ] ) AS ( <column_definition> [, ...] )
  [LATERAL] ROWS FROM( <function_name> ( [ <argument> [, ...] ] ) [ AS ( <column_definition> [, ...] ) ] [, ...] )
      [ WITH ORDINALITY ] [ [ AS ] <alias> [ ( <column_alias> [, ...] ) ] ]
  <from_item> <join_type> <from_item> { ON <join_condition> | USING ( <join_column> [, ...] ) }
  <from_item> NATURAL <join_type> <from_item>
  <from_item> CROSS JOIN <from_item>

where <grouping_element> can be one of:

  ()
  <expression>
  ROLLUP (<expression> [,...])
  CUBE (<expression> [,...])
  GROUPING SETS (<grouping_element> [, ...])

where <with_query> is:

  <with_query_name> [( <column_name> [, ...] )] AS ( [ NOT ] MATERIALIZED ] ( <select> | <values> | <insert> | <update> | delete )

TABLE [ ONLY ] <table_name> [ * ]
```

Description

`SELECT` retrieves rows from zero or more tables. The general processing of `SELECT` is as follows:

1. All queries in the `WITH` clause are computed. These effectively serve as temporary tables that can be referenced in the `FROM` list. A `WITH` query that is referenced more than once in `FROM` is computed only once, unless specified otherwise with `NOT MATERIALIZED`. (See WITH Clause below.)
2. All elements in the `FROM` list are computed. (Each element in the `FROM` list is a real or virtual table.) If more than one element is specified in the `FROM` list, they are cross-joined together. (See FROM Clause below.)
3. If the `WHERE` clause is specified, all rows that do not satisfy the condition are eliminated from the output. (See WHERE Clause below.)
4. If the `GROUP BY` clause is specified, or if there are aggregate function calls, the output is combined into groups of rows that match on one or more values, and the results of aggregate functions are computed. If the `HAVING` clause is present, it eliminates groups that do not satisfy the given condition. (See GROUP BY Clause and HAVING Clause below.)
5. The actual output rows are computed using the `SELECT` output expressions for each selected row or row group. (See SELECT List below.)
6. `SELECT DISTINCT` eliminates duplicate rows from the result. `SELECT DISTINCT ON` eliminates rows that match on all the specified expressions. `SELECT ALL` (the default) will return all candidate rows, including duplicates. (See DISTINCT Clause below.)
7. If a window expression is specified (and optional `WINDOW` clause), the output is organized according to the positional (row) or value-based (range) window frame. (See WINDOW Clause below.)
8. Using the operators `UNION`, `INTERSECT`, and `EXCEPT`, the output of more than one `SELECT` statement can be combined to form a single result set. The `UNION` operator returns all rows that are in one or both of the result sets. The `INTERSECT` operator returns all rows that are strictly in both result sets. The `EXCEPT` operator returns the rows that are in the first result set but not in the second. In all three cases, duplicate rows are eliminated unless `ALL` is specified. The noise word `DISTINCT` can be added to explicitly specify eliminating duplicate rows. Notice that `DISTINCT` is the default behavior here, even though `ALL` is the default for `SELECT` itself. (See UNION Clause, INTERSECT Clause, and EXCEPT Clause below.)
9. If the `ORDER BY` clause is specified, the returned rows are sorted in the specified order. If `ORDER BY` is not given, the rows are returned in whatever order the system finds fastest to produce. (See ORDER BY Clause below.)
10. If the `LIMIT` (or `FETCH FIRST`) or `OFFSET` clause is specified, the `SELECT` command only returns a subset of the result rows. (See LIMIT Clause below.)
11. If `FOR UPDATE`, `FOR NO KEY UPDATE`, `FOR SHARE`, or `FOR KEY SHARE` is specified, the `SELECT` command locks the entire table against concurrent updates when the Global Deadlock Detector is deactivated (the default). When the Global Deadlock Detector is activated, it affects some simple `SELECT` statements that contain a locking clause. (See The Locking Clause below.)

You must have `SELECT` privilege on each column used in a `SELECT` command. The use of `FOR NO KEY UPDATE`, `FOR UPDATE`, `FOR SHARE`, or `FOR KEY SHARE` requires `UPDATE` privilege as well (for at least one column of each table so selected).

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Parameters

The WITH Clause

The `WITH` clause allows you to specify one or more subqueries that can be referenced by name in the primary query. The subqueries effectively act as temporary tables or views for the duration of the primary query. Each subquery can be a `SELECT`, `TABLE`, `VALUES`, `INSERT`, `UPDATE`, or `DELETE` statement. When writing a data-modifying statement (`INSERT`, `UPDATE`, or `DELETE`) in `WITH`, it is usual to include a `RETURNING` clause. It is the output of `RETURNING`, *not* the underlying table that the statement modifies, that forms the temporary table that is read by the primary query. If `RETURNING` is omitted, the statement is still run, but it produces no output so it cannot be referenced as a table by the primary query.

For a `SELECT` command that includes a `WITH` clause, the clause can contain at most a single clause that modifies table data (`INSERT`, `UPDATE`, or `DELETE` command).

A name (without schema qualification) must be specified for each `WITH` query. Optionally, you can specify a list of column names; if this is omitted, the names are inferred from the subquery.

If `RECURSIVE` is specified, it allows a `SELECT` subquery to reference itself by name. Such a subquery must have the form:

```
<non_recursive_term> UNION [ALL | DISTINCT] <recursive_term>
```

where the recursive self-reference appears on the right-hand side of the `UNION`. Only one recursive self-reference is permitted per query. Recursive data-modifying statements are not supported, but you can use the results of a recursive `SELECT` query in a data-modifying statement.

If the `RECURSIVE` keyword is specified, the `WITH` queries need not be ordered: a query can reference another query that is later in the list. However, circular references, or mutual recursion, are not supported. Without the `RECURSIVE` keyword, `WITH` queries can reference only sibling `WITH` queries that are earlier in the `WITH` list.

When there are multiple queries in the `WITH` clause, `RECURSIVE` should be written only once, immediately after `WITH`. It applies to all queries in the `WITH` clause, though it has no effect on queries that do not use recursion or forward references.

`WITH RECURSIVE` limitations. These items are not supported:

- A recursive `WITH` clause that contains the following in the `<recursive_term>`.
  - Subqueries with a self-reference
  - `DISTINCT` clause
  - `GROUP BY` clause
  - A window function
- A recursive `WITH` clause where the `<with_query_name>` is a part of a set operation.

Following is an example of the set operation limitation. This query returns an error because the set operation `UNION` contains a reference to the table `foo`.

```
WITH RECURSIVE foo(i) AS (
    SELECT 1
  UNION ALL
    SELECT i+1 FROM (SELECT * FROM foo UNION SELECT 0) bar
)
SELECT * FROM foo LIMIT 5;
```

This recursive CTE is allowed because the set operation `UNION` does not have a reference to the CTE `foo`.

```
WITH RECURSIVE foo(i) AS (
    SELECT 1
  UNION ALL
    SELECT i+1 FROM (SELECT * FROM bar UNION SELECT 0) bar, foo
    WHERE foo.i = bar.a
)
SELECT * FROM foo LIMIT 5;
```

The primary query and the `WITH` queries are all (notionally) run at the same time. This implies that the effects of a data-modifying statement in `WITH` cannot be seen from other parts of the query, other than by reading its `RETURNING` output. If two such data-modifying statements attempt to modify the same row, the results are unspecified.

A key property of `WITH` queries is that they are evaluated only once per execution of the primary query, even if the primary query refers to them more than once. In particular, data-modifying statements are guaranteed to be run once and only once, regardless of whether the primary query reads all or any of their output.

However, a `WITH` query can be marked `NOT MATERIALIZED` to remove this guarantee. In that case, the `WITH` query can be folded into the primary query much as though it were a simple sub `SELECT` in the primary query's `FROM` clause. This results in duplicate computations if the primary query refers to that `WITH` query more than once; but if each such use requires only a few rows of the `WITH` query's total output, `NOT MATERIALIZED` can provide a net savings by allowing the queries to be optimized jointly. `NOT MATERIALIZED` is ignored if it is attached to a `WITH` query that is recursive or is not side-effect-free (for example, is not a plain `SELECT` containing no volatile functions).

By default, a side-effect-free `WITH` query is folded into the primary query if it is used exactly once in the primary query's `FROM` clause. This allows joint optimization of the two query levels in situations where that should be semantically invisible. However, such folding can be prevented by marking the `WITH` query as `MATERIALIZED`. That might be useful, for example, if the `WITH` query is being used as an optimization fence to prevent the planner from choosing a bad plan. WarehousePG versions before 7 never did such folding, so queries written for older versions might rely on `WITH` to act as an optimization fence.

See WITH Queries (Common Table Expressions) in the *WarehousePG Administrator Guide* for additional information.

The FROM Clause

The `FROM` clause specifies one or more source tables for the `SELECT`. If multiple sources are specified, the result is the Cartesian product (cross join) of all the sources. But usually qualification conditions are added (via `WHERE`) to restrict the returned rows to a small subset of the Cartesian product.

The `FROM` clause can contain the following elements:

table_name The name (optionally schema-qualified) of an existing table or view. If `ONLY` is specified before the table name, only that table is scanned. If `ONLY` is not specified, the table and all of its descendant tables (if any) are scanned. Optionally, you can specify `*` after the table name to explicitly indicate that descendant tables are included.

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alias A substitute name for the `FROM` item containing the alias. An alias is used for brevity or to eliminate ambiguity for self-joins (where the same table is scanned multiple times). When you provide an alias, it completely hides the actual name of the table or function; for example given `FROM foo AS f`, the remainder of the `SELECT` must refer to this `FROM` item as `f` not `foo`. If you specify an alias, you can also specify a column alias list to provide substitute names for one or more columns of the table.

TABLESAMPLE sampling_method (argument [, ...]) [REPEATABLE (seed)] A `TABLESAMPLE` clause after a `table_name` indicates that the specified sampling_method should be used to retrieve a subset of the rows in that table. This sampling precedes the application of any other filters such as `WHERE` clauses. The standard WarehousePG distribution includes two sampling methods, `BERNOULLI` and `SYSTEM`. You can install the additional sampling methods `SYSTEM_ROWS` and `SYSTEM_TIME` in the database via extensions.

The `BERNOULLI` and `SYSTEM` sampling methods each accept a single argument which is the fraction of the table to sample, expressed as a percentage between 0 and 100. This argument can be any real-valued expression. (Other sampling methods might accept more or different arguments.) These two methods each return a randomly-chosen sample of the table that will contain approximately the specified percentage of the table's rows. The `BERNOULLI` method scans the whole table and selects or ignores individual rows independently with the specified probability. The `SYSTEM` method does block-level sampling with each block having the specified chance of being selected; all rows in each selected block are returned. The `SYSTEM` method is significantly faster than the `BERNOULLI` method when small sampling percentages are specified, but it may return a less-random sample of the table as a result of clustering effects.

The `SYSTEM ROWS` table sampling method accepts a single integer argument that is the maximum number of rows to read. The resulting sample will always contain exactly that many rows, unless the table does not contain enough rows, in which case the whole table is selected.

The `SYSTEM_TIME` table sampling method takes a single floating-point argument that specifies the maximum number of milliseconds to spend reading the table. This allows you to control how long the query takes; the tradeoff is that the size of the sample becomes hard to predict. The resulting sample will contain as many rows as could be read in the specified time, unless the whole table has been read first.

Like the built-in `SYSTEM` sampling method, `SYSTEM_ROWS` and `SYSTEM_TIME` perform block-level sampling, so that, rather than being completely random, the sample may be subject to clustering effects, particularly when a small number of rows are selected.

> **IMPORTANT** To call the `SYSTEM_ROWS` and `SYSTEM_TIME` sampling methods, you must install the WarehousePG extensions that provide access to them: `tsm_system_rows` and `tsm_system_time`, repectively. See the tsm_system_rows and tsm_system_time topics for details.

Sampling performance on append-optimized tables will improve if the table has a block directory (if the table has any index or had any index in the past) and the improvement is directly proportional to the degree of compression of the table and inversely proportional to the size of the sample requested. To create a block directory for a table that doesn't have an index, issue the following command:

```
CREATE INDEX dummy ON tab(i) WHERE false; DROP INDEX dummy;
```

The optional `REPEATABLE` clause specifies a seed number or expression to use for generating random numbers within the sampling method. The seed value can be any non-null floating-point value. Two queries that specify the same seed and argument values will select the same sample of the table, if the table has not been changed meanwhile. But different seed values usually produce different samples. If `REPEATABLE` is not specified, then WarehousePG selects a new random sample for each query, based upon a system-generated seed. Note that some add-on sampling methods do not accept `REPEATABLE`, and will always produce new samples on each use.

select A sub-`SELECT` can appear in the `FROM` clause. This acts as though its output were created as a temporary table for the duration of this single `SELECT` command. Note that the sub-`SELECT` must be surrounded by parentheses, and an alias *must* be provided for it. A VALUES command can also be used here. See "Non-standard Clauses" in theCompatibility section for limitations of using correlated sub-selects in WarehousePG.

with_query_name A `WITH` query is referenced in the `FROM` clause by specifying its name, just as though the name were a table name. You can provide an alias in the same way as for a table.

The `WITH` query hides a table of the same name for the purposes of the primary query. If necessary, you can refer to a table of the same name by schema-qualifying the table's name.

function_name Function calls can appear in the `FROM` clause. (This is especially useful for functions that return result sets, but any function can be used.) This acts as though the function's output were created as a temporary table for the duration of this single `SELECT` command. When you add the optional `WITH ORDINALITY` clause to the function call, WarehousePG appends a new column after all of the function's output columns with numbering for each row. You can provide an alias in the same way as for a table. If an alias is specified, you can also specify a column alias list to provide substitute names for one or more attributes of the function's composite return type, including the column added by `ORDINALITY` if present. You can combine multiple function calls into a single `FROM`-clause item by surrounding them with `ROWS FROM( ... )`. The output of such an item is the concatenation of the first row from each function, then the second row from each function, etc. If some of the functions produce fewer rows than others, null values are substituted for the missing data, so that the total number of rows returned is always the same as for the function that produced the most rows. If the function has been defined as returning the `record` data type, then an alias or the key word `AS` must be present, followed by a column definition list in the form `( <column_name> <data_type> [, ... ] )`. The column definition list must match the actual number and types of columns returned by the function. When using the `ROWS FROM( ... )` syntax, if one of the functions requires a column definition list, it's preferred to put the column definition list after the function call inside `ROWS FROM( ... )`. A column definition list can be placed after the `ROWS FROM( ... )` construct only if there's just a single function and no `WITH ORDINALITY` clause. To use `ORDINALITY` together with a column definition list, you must use the `ROWS FROM( ... )` syntax and put the column definition list inside `ROWS FROM( ... )`.

join_type One of:

- `[INNER] JOIN`
- `LEFT [OUTER] JOIN`
- `RIGHT [OUTER] JOIN`
- `FULL [OUTER] JOIN`

For the `INNER` and `OUTER` join types, you must specify a join condition, namely exactly one of `NATURAL`, `ON <join_condition>`, or `USING ( <join_column> [, ...])`. Continue reading for the meaning.

A JOIN clause combines two `FROM` items, which for convenience are referred to as "tables", though in reality they can be any type of `FROM` item. Use parentheses if necessary to determine the order of nesting. In the absence of parentheses, `JOIN`s nest left-to-right. `JOIN` binds more tightly than the commas separating `FROM`-list items. All of the `JOIN` options are a notational convenience; they do nothing that cannot be achieved with plain `FROM` and `WHERE`.

`LEFT OUTER JOIN` returns all rows in the qualified Cartesian product (i.e., all combined rows that pass its join condition), plus one copy of each row in the left-hand table for which there was no right-hand row that passed the join condition. This left-hand row is extended to the full width of the joined table by inserting null values for the right-hand columns. Note that only the `JOIN` clause's own condition is considered while deciding which rows have matches. Outer conditions are applied afterwards.

Conversely, `RIGHT OUTER JOIN` returns all the joined rows, plus one row for each unmatched right-hand row (extended with nulls on the left). This is just a notational convenience, since you could convert it to a `LEFT OUTER JOIN` by switching the left and right tables.

`FULL OUTER JOIN` returns all the joined rows, plus one row for each unmatched left-hand row (extended with nulls on the right), plus one row for each unmatched right-hand row (extended with nulls on the left).

ON join_condition join_condition is an expression resulting in a value of type `boolean` (similar to a `WHERE` clause) that specifies which rows in a join are considered to match.

USING (join_column [, ...]) A clause of the form `USING ( a, b, ... )` is shorthand for `ON left_table.a = right_table.a AND left_table.b = right_table.b ...`. Also, `USING` implies that only one of each pair of equivalent columns will be included in the join output, not both.

NATURAL `NATURAL` is shorthand for a `USING` list that mentions all columns in the two tables that have the same names. If there are no common column names, `NATURAL` is equivalent to `ON TRUE`.

CROSS JOIN `CROSS JOIN` is equivalent to `INNER JOIN ON (TRUE)`, that is, no rows are removed by qualification. They produce a simple Cartesian product, the same result as you get from listing the two tables at the top level of `FROM`, but restricted by the join condition (if any).

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LATERAL The `LATERAL` key word can precede a sub-`SELECT FROM` item. This allows the sub-`SELECT` to refer to columns of `FROM` items that appear before it in the `FROM` list. (Without `LATERAL`, WarehousePG evaluates each sub-`SELECT` independently and so cannot cross-reference any other `FROM` item.)

`LATERAL` can also precede a function-call `FROM` item. In this case it is a noise word, because the function expression can refer to earlier `FROM` items.

A `LATERAL` item can appear at top level in the `FROM` list, or within a `JOIN` tree. In the latter case it can also refer to any items that are on the left-hand side of a `JOIN` that it is on the right-hand side of.

When a `FROM` item contains `LATERAL` cross-references, evaluation proceeds as follows: for each row of the `FROM` item providing the cross-referenced column(s), or set of rows of multiple `FROM` items providing the columns, the `LATERAL` item is evaluated using that row or row set's values of the columns. The resulting row(s) are joined as usual with the rows they were computed from. This is repeated for each row or set of rows from the column source table(s).

The column source table(s) must be `INNER` or `LEFT` joined to the `LATERAL` item, else there would not be a well-defined set of rows from which to compute each set of rows for the `LATERAL` item. Thus, although a construct such as `<X> RIGHT JOIN LATERAL <Y>` is syntactically valid, WarehousePG does not permit `<Y>` to reference `<X>`.

The WHERE Clause

The optional `WHERE` clause has the general form:

```
WHERE <condition>
```

where condition is any expression that evaluates to a result of type `boolean`. Any row that does not satisfy this condition will be eliminated from the output. A row satisfies the condition if it returns true when the actual row values are substituted for any variable references.

The GROUP BY Clause

The optional `GROUP BY` clause has the general form:

```
GROUP BY <grouping_element> [, ...]
```

where `<grouping_element>` can be one of:

```
()
<expression>
ROLLUP (<expression> [,...])
CUBE (<expression> [,...])
GROUPING SETS ((<grouping_element> [, ...]))
```

`GROUP BY` condenses into a single row all selected rows that share the same values for the grouped expressions. An expression used inside a grouping_element can be an input column name, or the name or ordinal number of an output column (`SELECT` list item), or an arbitrary expression formed from input-column values. In case of ambiguity, a `GROUP BY` name will be interpreted as an input-column name rather than an output column name.

If any of `GROUPING SETS`, `ROLLUP`, or `CUBE` are present as grouping elements, then the `GROUP BY` clause as a whole defines some number of independent grouping sets. The effect of this is equivalent to constructing a `UNION ALL` between subqueries with the individual grouping sets as their `GROUP BY` clauses. For further details on the handling of grouping sets, refer to GROUPING SETS, CUBE, and ROLLUP in the PostgreSQL documentation.

Aggregate functions, if any are used, are computed across all rows making up each group, producing a separate value for each group. (If there are aggregate functions but no `GROUP BY` clause, the query is treated as having a single group comprising all of the selected rows.) You can further filter the set of rows fed to each aggregate function by attaching a `FILTER` clause to the aggregate function call. When a `FILTER` clause is present, only those rows matching it are included in the input to that aggregate function. See Aggregate Expressions.

When `GROUP BY` is present, or any aggregate functions are present, it is not valid for the `SELECT` list expressions to refer to ungrouped columns except within aggregate functions or when the ungrouped column is functionally dependent on the grouped columns, since there would otherwise be more than one possible value to return for an ungrouped column. A functional dependency exists if the grouped columns (or a subset thereof) are the primary key of the table containing the ungrouped column.

Keep in mind that all aggregate functions are evaluated before evaluating any "scalar" expressions in the `HAVING` clause or `SELECT` list. This means that, for example, a `CASE` expression cannot be used to skip evaluation of an aggregate function; see Expression Evaluation Rules.

Currently, `FOR NO KEY UPDATE`, `FOR UPDATE`, `FOR SHARE`, and `FOR KEY SHARE` cannot be specified with `GROUP BY`.

WarehousePG has the following additional OLAP grouping extensions (often referred to as *supergroups*):

ROLLUP A `ROLLUP` grouping is an extension to the `GROUP BY` clause that creates aggregate subtotals that roll up from the most detailed level to a grand total, following a list of grouping columns (or expressions). `ROLLUP` takes an ordered list of grouping columns, calculates the standard aggregate values specified in the `GROUP BY` clause, then creates progressively higher-level subtotals, moving from right to left through the list. Finally, it creates a grand total. A `ROLLUP` grouping can be thought of as a series of grouping sets. For example:

```
```
GROUP BY ROLLUP (a,b,c)
```

is equivalent to:

```
GROUP BY GROUPING SETS( (a,b,c), (a,b), (a), () )
```

Notice that the n elements of a `ROLLUP` translate to n+1 grouping sets. Also, the order in which the grouping expressions are specified is significant in a `ROLLUP`.
```

CUBE A `CUBE` grouping is an extension to the `GROUP BY` clause that creates subtotals for all of the possible combinations of the given list of grouping columns (or expressions). In terms of multidimensional analysis, `CUBE` generates all the subtotals that could be calculated for a data cube with the specified dimensions. For example:

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```
GROUP BY CUBE (a,b,c)
```

is equivalent to:

```
GROUP BY GROUPING SETS( (a,b,c), (a,b), (a,c), (b,c), (a),
(b), (c), () )
```

Notice that n elements of a `CUBE` translate to 2n grouping sets. Consider using `CUBE` in any situation requiring cross-tabular reports. `CUBE` is typically most suitable in queries that use columns from multiple dimensions rather than columns representing different levels of a single dimension. For instance, a commonly requested cross-tabulation might need subtotals for all the combinations of month, state, and product.

GROUPING SETS You can selectively specify the set of groups that you want to create using a `GROUPING SETS` expression within a `GROUP BY` clause. This allows precise specification across multiple dimensions without computing a whole `ROLLUP` or `CUBE`. For example:

```
GROUP BY GROUPING SETS( (a,c), (a,b) )
```

If using the grouping extension clauses `ROLLUP`, `CUBE`, or `GROUPING SETS`, two challenges arise. First, how do you determine which result rows are subtotals, and then the exact level of aggregation for a given subtotal. Or, how do you differentiate between result rows that contain both stored `NULL` values and "NULL" values created by the `ROLLUP` or `CUBE`. Secondly, when duplicate grouping sets are specified in the `GROUP BY` clause, how do you determine which result rows are duplicates? There are two additional grouping functions you can use in the `SELECT` list to help with this:

- **grouping(column [, ...])** — The `grouping` function can be applied to one or more grouping attributes to distinguish super-aggregated rows from regular grouped rows. This can be helpful in distinguishing a "NULL" representing the set of all values in a super-aggregated row from a `NULL` value in a regular row. Each argument in this function produces a bit — either `1` or `0`, where `1` means the result row is super-aggregated, and `0` means the result row is from a regular grouping. The `grouping` function returns an integer by treating these bits as a binary number and then converting it to a base-10 integer.
- **group_id()** — For grouping extension queries that contain duplicate grouping sets, the `group_id` function is used to identify duplicate rows in the output. All *unique* grouping set output rows will have a `<group_id>` value of 0. For each duplicate grouping set detected, the `group_id` function assigns a `<group_id>` number greater than 0. All output rows in a particular duplicate grouping set are identified by the same `<group_id>` number.

The HAVING Clause

The optional `HAVING` clause has the general form:

```
HAVING <condition>
```

where `<condition>` is the same as specified for the `WHERE` clause.

`HAVING` eliminates group rows that do not satisfy the condition. `HAVING` is different from `WHERE`: `WHERE` filters individual rows before the application of `GROUP BY`, while `HAVING` filters group rows created by `GROUP BY`. Each column referenced in `<condition>` must unambiguously reference a grouping column, unless the reference appears within an aggregate function or the ungrouped column is functionally dependent on the grouping columns.

The presence of `HAVING` turns a query into a grouped query even if there is no `GROUP BY` clause. This is the same as what happens when the query contains aggregate functions but no `GROUP BY` clause. All of the selected rows are considered to form a single group, and the `SELECT` list and `HAVING` clause can only reference table columns from within aggregate functions. Such a query will emit a single row if the `HAVING` condition is true, zero rows if it is not true.

Currently, `FOR NO KEY UPDATE`, `FOR UPDATE`, `FOR SHARE`, and `FOR KEY SHARE` cannot be specified with `HAVING`.

The WINDOW Clause

The optional `WINDOW` clause specifies the behavior of window functions appearing in the query's `SELECT` list or `ORDER BY` clause. The `WINDOW` clause has the general form:

```
WINDOW <window_name> AS ( <window_definition> ) [, ...]
```

where `<window_name>` is a name that can be referenced from `OVER` clauses or subsequent window definitions, and `<window_definition>` is:

```
[<existing_window_name>]
[PARTITION BY <expression> [, ...]]
[ORDER BY <expression> [ASC | DESC | USING <operator>] [NULLS {FIRST | LAST}] [, ...] ]
[<frame_clause>]
```

A `WINDOW` clause entry does not have to be referenced anywhere, however; if it is not used in the query it is simply ignored. It is possible to use window functions without any `WINDOW` clause at all, since a window function call can specify its window definition directly in its `OVER` clause. However, the `WINDOW` clause saves typing when the same window definition is needed for more than one window function.

For example:

```
SELECT vendor, rank() OVER (mywindow) FROM sale
GROUP BY vendor
WINDOW mywindow AS (ORDER BY sum(prc*qty));
```

existing_window_name If an existing_window_name is specified, it must refer to an earlier entry in the `WINDOW` list; the new window copies its partitioning clause from that entry, as well as its ordering clause if any. The new window cannot specify its own `PARTITION BY` clause, and it can specify `ORDER BY` only if the copied window does not have one. The new window always uses its own frame clause; the copied window must not specify a frame clause.

PARTITION BY The `PARTITION BY` clause organizes the result set into logical groups based on the unique values of the specified expression. The elements of the `PARTITION BY` clause are interpreted in much the same fashion as elements of a GROUP BY Clause, except that they are always simple expressions and never the name or number of an output column. Another difference is that these expressions can contain aggregate function calls, which are not allowed in a regular `GROUP BY` clause. They are allowed here because windowing occurs after grouping and aggregation. When used with window functions, the functions are applied to each partition independently. For example, if you follow `PARTITION BY` with a column name, the result set is partitioned by the distinct values of that column. If omitted, the entire result set is considered one partition.

ORDER BY Similarly, the elements of the `ORDER BY` list are interpreted in much the same fashion as elements of an ORDER BY Clause, except that the expressions are always taken as simple expressions and never the name or number of an output column.

> **Note** The elements of the `ORDER BY` clause define how to sort the rows in each partition of the result set. If omitted, rows are returned in whatever order is most efficient and may vary.

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frame_clause The optional frame_clause defines the *window frame* for window functions that depend on the frame (not all do). The window frame is a set of related rows for each row of the query (called the *current row*). The frame_clause can be one of

```
{ RANGE | ROWS | GROUPS } <frame_start> [ <frame_exclusion> ]
{ RANGE | ROWS | GROUPS } BETWEEN <frame_start> AND <frame_end> [ <frame_exclusion> ]
```

where `<frame_start>` and `<frame_end>` can be one of

```
UNBOUNDED PRECEDING
<offset> PRECEDING
CURRENT ROW
<offset> FOLLOWING
UNBOUNDED FOLLOWING
```

and `<frame_exclusion>` can be one of

```
EXCLUDE CURRENT ROW
EXCLUDE GROUP
EXCLUDE TIES
EXCLUDE NO OTHERS
```

If `<frame_end>` is omitted it defaults to `CURRENT ROW`. Restrictions are that `<frame_start>` cannot be `UNBOUNDED FOLLOWING`, `<frame_end>` cannot be `UNBOUNDED PRECEDING`, and the `<frame_end>` choice cannot appear earlier in the above list of `<frame_start>` and `<frame_end>` options than the `<frame_start>` choice does — for example `RANGE BETWEEN CURRENT ROW AND <offset> PRECEDING` is not allowed.

The default framing option is `RANGE UNBOUNDED PRECEDING`, which is the same as `RANGE BETWEEN UNBOUNDED PRECEDING AND CURRENT ROW`; it sets the frame to be all rows from the partition start up through the current row's last peer (a row that the window's `ORDER BY` clause considers equivalent to the current row; all rows are peers if there is no `ORDER BY`). In general, `UNBOUNDED PRECEDING` means that the frame starts with the first row of the partition, and similarly `UNBOUNDED FOLLOWING` means that the frame ends with the last row of the partition, regardless of `RANGE`, `ROWS` or `GROUPS` mode. In `ROWS` mode, `CURRENT ROW` means that the frame starts or ends with the current row; but in `RANGE` or `GROUPS` mode it means that the frame starts or ends with the current row's first or last peer in the `ORDER BY` ordering. The `<offset> PRECEDING` and `<offset> FOLLOWING` options vary in meaning depending on the frame mode. In `ROWS` mode, the `<offset>` is an integer indicating that the frame starts or ends that many rows before or after the current row. In `GROUPS` mode, the `<offset>` is an integer indicating that the frame starts or ends that many peer groups before or after the current row's peer group, where a peer group is a group of rows that are equivalent according to the window's `ORDER BY` clause. In `RANGE` mode, use of an `<offset>` option requires that there be exactly one `ORDER BY` column in the window definition. Then the frame contains those rows whose ordering column value is no more than `<offset>` less than (for `PRECEDING`) or more than (for `FOLLOWING`) the current row's ordering column value. In these cases the data type of the `<offset>` expression depends on the data type of the ordering column. For numeric ordering columns it is typically of the same type as the ordering column, but for datetime ordering columns it is an `interval`. In all these cases, the value of the `<offset>` must be non-null and non-negative. Also, while the offset does not have to be a simple constant, it cannot contain variables, aggregate functions, or window functions.

The `<frame_exclusion>` option allows rows around the current row to be excluded from the frame, even if they would be included according to the frame start and frame end options. `EXCLUDE CURRENT ROW` excludes the current row from the frame. `EXCLUDE GROUP` excludes the current row and its ordering peers from the frame. `EXCLUDE TIES` excludes any peers of the current row from the frame, but not the current row itself. `EXCLUDE NO OTHERS` simply specifies explicitly the default behavior of not excluding the current row or its peers.

Beware that the `ROWS` mode can produce unpredictable results if the `ORDER BY` ordering does not order the rows uniquely. The `RANGE` and `GROUPS` modes are designed to ensure that rows that are peers in the `ORDER BY` ordering are treated alike: all rows of a given peer group will be in the frame or excluded from it.

Use either a `ROWS`, `RANGE`, or `GROUPS` clause to express the bounds of the window. The window bound can be one, many, or all rows of a partition. You can express the bound of the window either in terms of a range of data values offset from the value in the current row (`RANGE`), in terms of the number of rows offset from the current row (`ROWS`), or in terms of the number of peer groups (`GROUPS`). When using the `RANGE` or the `GROUPS` clause, you must also use an `ORDER BY` clause. This is because the calculation performed to produce the window requires that the values be sorted. Additionally, the `ORDER BY` clause cannot contain more than one expression, and the expression must result in either a date or a numeric value. When using the `ROWS`, `RANGE` or `GROUPS` clauses, if you specify only a starting row, the current row is used as the last row in the window.

PRECEDING — The `PRECEDING` clause defines the first row of the window using the current row as a reference point. The starting row is expressed in terms of the number of rows preceding the current row. For example, in the case of `ROWS` framing, `5 PRECEDING` sets the window to start with the fifth row preceding the current row. In the case of `RANGE` framing, it sets the window to start with the first row whose ordering column value precedes that of the current row by 5 in the given order. If the specified order is ascending by date, this will be the first row within 5 days before the current row. `UNBOUNDED PRECEDING` sets the first row in the window to be the first row in the partition.

BETWEEN — The `BETWEEN` clause defines the first and last row of the window, using the current row as a reference point. First and last rows are expressed in terms of the number of rows preceding and following the current row, respectively. For example, `BETWEEN 3 PRECEDING AND 5 FOLLOWING` sets the window to start with the third row preceding the current row, and end with the fifth row following the current row. Use `BETWEEN UNBOUNDED PRECEDING AND UNBOUNDED FOLLOWING` to set the first and last rows in the window to be the first and last row in the partition, respectively. This is equivalent to the default behavior if no `ROWs`, `RANGE` or `GROUPS` clause is specified.

FOLLOWING — The `FOLLOWING` clause defines the last row of the window using the current row as a reference point. The last row is expressed in terms of the number of rows following the current row. For example, in the case of `ROWS` framing, `5 FOLLOWING` sets the window to end with the fifth row following the current row. In the case of `RANGE` framing, it sets the window to end with the last row whose ordering column value follows that of the current row by 5 in the given order. If the specified order is ascending by date, this will be the last row within 5 days after the current row. Use `UNBOUNDED FOLLOWING` to set the last row in the window to be the last row in the partition.

If you do not specify a `ROWS`, a `RANGE` or a `GROUPS` clause, the window bound starts with the first row in the partition (`UNBOUNDED PRECEDING`) and ends with the current row (`CURRENT ROW`) if `ORDER BY` is used. If an `ORDER BY` is not specified, the window starts with the first row in the partition (`UNBOUNDED PRECEDING`) and ends with last row in the partition (`UNBOUNDED FOLLOWING`).

The purpose of a `WINDOW` clause is to specify the behavior of window functions appearing in the query's SELECT List or ORDER BY Clause. These functions can reference the `WINDOW` clause entries by name in their `OVER` clauses. A `WINDOW` clause entry does not have to be referenced anywhere, however; if it is not used in the query it is simply ignored. It is possible to use window functions without any `WINDOW` clause at all, since a window function call can specify its window definition directly in its `OVER` clause. However, the `WINDOW` clause saves typing when the same window definition is needed for more than one window function.

Currently, `FOR NO KEY UPDATE`, `FOR UPDATE`, `FOR SHARE`, and `FOR KEY SHARE` cannot be specified with `WINDOW`.

See Window Expressions for more information about window functions.

The SELECT List

The `SELECT` list (between the key words `SELECT` and `FROM`) specifies expressions that form the output rows of the `SELECT` statement. The expressions can (and usually do) refer to columns computed in the `FROM` clause.

An expression in the `SELECT` list can be a constant value, a column reference, an operator invocation, a function call, an aggregate expression, a window expression, a scalar subquery, and so on. A number of constructs can be classified as an expression but do not follow any general syntax rules. These generally have the semantics of a function or operator. For information about SQL value expressions and function calls, see SQL: Querying Data in the *WarehousePG Administrator Guide*.

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Just as in a table, every output column of a `SELECT` has a name. In a simple `SELECT` this name is just used to label the column for display, but when the `SELECT` is a sub-query of a larger query, the name is seen by the larger query as the column name of the virtual table produced by the sub-query. To specify the name to use for an output column, write `AS <output_name>` after the column's expression. (You can omit `AS`, but only if the desired output name does not match any SQL keyword. For protection against possible future keyword additions, you can always either write `AS` or double-quote the output name.) If you do not specify a column name, WarehousePG chooses a name automatically. If the column's expression is a simple column reference then the chosen name is the same as that column's name. In more complex cases, a function or type name may be used, or the system may fall back on a generated name such as `?column?` or `columnN`.

An output column's name can be used to refer to the column's value in `ORDER BY` and `GROUP BY` clauses, but not in the `WHERE` or `HAVING` clauses; there you must specify the expression instead.

Instead of an expression, you can specify `*` in the output list as a shorthand for all the columns of the selected rows. Also, you can specify `<table_name>.*` as a shorthand for the columns coming from just that table. In these cases it is not possible to specify new names with `AS`; the output column names will be the same as the table columns' names.

According to the SQL standard, the expressions in the output list should be computed before applying `DISTINCT`, `ORDER BY`, or `LIMIT`. This is obviously necessary when using `DISTINCT`, since otherwise it's not clear what values are being made distinct. However, in many cases it is convenient if output expressions are computed after `ORDER BY` and `LIMIT`; particularly if the output list contains any volatile or expensive functions. With that behavior, the order of function evaluations is more intuitive and there will not be evaluations corresponding to rows that never appear in the output. WarehousePG effectively evaluates output expressions after sorting and limiting, so long as those expressions are not referenced in `DISTINCT`, `ORDER BY`, or `GROUP BY`. (As a counterexample, `SELECT f(x) FROM tab ORDER BY 1` clearly must evaluate `f(x)` before sorting.) Output expressions that contain set-returning functions are effectively evaluated after sorting and before limiting, so that `LIMIT` will act to cut off the output from a set-returning function.

> **Note** WarehousePG versions prior to 7 did not provide any guarantees about the timing of evaluation of output expressions versus sorting and limiting; it depended on the form of the chosen query plan.

The DISTINCT Clause

If `SELECT DISTINCT` is specified, all duplicate rows are removed from the result set (one row is kept from each group of duplicates). `SELECT ALL` specifies the opposite: all rows are kept; that is the default.

`SELECT DISTINCT ON ( <expression> [, ...] )` keeps only the first row of each set of rows where the given expressions evaluate to equal. The `DISTINCT ON` expressions are interpreted using the same rules as for `ORDER BY` (see above). Note that the "first row" of each set is unpredictable unless `ORDER BY` is used to ensure that the desired row appears first. For example:

```
SELECT DISTINCT ON (location) location, time, report
    FROM weather_reports
    ORDER BY location, time DESC;
```

retrieves the most recent weather report for each location. But if we had not used `ORDER BY` to force descending order of time values for each location, we'd have gotten a report from an unpredictable time for each location.

The `DISTINCT ON` expression(s) must match the leftmost `ORDER BY` expression(s). The `ORDER BY` clause will normally contain additional expression(s) that determine the desired precedence of rows within each `DISTINCT ON` group.

Currently, `FOR NO KEY UPDATE`, `FOR UPDATE`, `FOR SHARE`, and `FOR KEY SHARE` cannot be specified with `DISTINCT`.

The UNION Clause

The `UNION` clause has this general form:

```
<select_statement> UNION [ALL | DISTINCT] <select_statement>
```

`<select_statement>` is any `SELECT` statement without an `ORDER BY`, `LIMIT`, `FOR NO KEY UPDATE`, `FOR UPDATE`, `FOR SHARE`, or `FOR KEY SHARE` clause. (`ORDER BY` and `LIMIT` can be attached to a subquery expression if it is enclosed in parentheses. Without parentheses, these clauses will be taken to apply to the result of the `UNION`, not to its right-hand input expression.)

The `UNION` operator computes the set union of the rows returned by the involved `SELECT` statements. A row is in the set union of two result sets if it appears in at least one of the result sets. The two `SELECT` statements that represent the direct operands of the `UNION` must produce the same number of columns, and corresponding columns must be of compatible data types.

The result of `UNION` does not contain any duplicate rows unless the `ALL` option is specified. `ALL` prevents elimination of duplicates. (Therefore, `UNION ALL` is usually significantly quicker than `UNION`; use `ALL` when you can.) `DISTINCT` can be specified to explicitly specify the default behavior of eliminating duplicate rows.

Multiple `UNION` operators in the same `SELECT` statement are evaluated left to right, unless otherwise indicated by parentheses.

Currently, `FOR NO KEY UPDATE`, `FOR UPDATE`, `FOR SHARE`, and `FOR KEY SHARE` cannot be specified either for a `UNION` result or for any input of a `UNION`.

The INTERSECT Clause

The `INTERSECT` clause has this general form:

```
<select_statement> INTERSECT [ALL | DISTINCT] <select_statement>
```

`<select_statement>` is any `SELECT` statement without an `ORDER BY`, `LIMIT`, `FOR NO KEY UPDATE`, `FOR UPDATE`, `FOR SHARE`, or `FOR KEY SHARE` clause.

The `INTERSECT` operator computes the set intersection of the rows returned by the involved `SELECT` statements. A row is in the intersection of two result sets if it appears in both result sets.

The result of `INTERSECT` does not contain any duplicate rows unless the `ALL` option is specified. With `ALL`, a row that has `<m>` duplicates in the left table and `<n>` duplicates in the right table will appear `min(<m>, <n>)` times in the result set. `DISTINCT` can be written to explicitly specify the default behavior of eliminating duplicate rows.

Multiple `INTERSECT` operators in the same `SELECT` statement are evaluated left to right, unless parentheses dictate otherwise. `INTERSECT` binds more tightly than `UNION`. That is, `A UNION B INTERSECT C` will be read as `A UNION (B INTERSECT C)`.

Currently, `FOR NO KEY UPDATE`, `FOR UPDATE`, `FOR SHARE`, and `FOR KEY SHARE` cannot be specified either for an `INTERSECT` result or for any input of an `INTERSECT`.

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The EXCEPT Clause

The `EXCEPT` clause has this general form:

```
<select_statement> EXCEPT [ALL | DISTINCT] <select_statement>
```

`<select_statement>` is any `SELECT` statement without an `ORDER BY`, `LIMIT`, `FOR NO KEY UPDATE`, `FOR UPDATE`, `FOR SHARE`, or `FOR KEY SHARE` clause.

The `EXCEPT` operator computes the set of rows that are in the result of the left `SELECT` statement but not in the result of the right one.

The result of `EXCEPT` does not contain any duplicate rows unless the `ALL` option is specified. With `ALL`, a row that has `<m>` duplicates in the left table and `<n>` duplicates in the right table will appear `max(<m>-<n>,0)` times in the result set. `DISTINCT` can be written to explicitly specify the default behavior of eliminating duplicate rows.

Multiple `EXCEPT` operators in the same `SELECT` statement are evaluated left to right, unless parentheses dictate otherwise. `EXCEPT` binds at the same level as `UNION`.

Currently, `FOR NO KEY UPDATE`, `FOR UPDATE`, `FOR SHARE`, and `FOR KEY SHARE` cannot be specified either for an `EXCEPT` result or for any input of an `EXCEPT`.

The ORDER BY Clause

The optional `ORDER BY` clause has this general form:

```
ORDER BY <expression> [ASC | DESC | USING <operator>] [NULLS {FIRST | LAST}] [,...]
```

The `ORDER BY` clause causes the result rows to be sorted according to the specified expression(s). If two rows are equal according to the left-most expression, they are compared according to the next expression and so on. If they are equal according to all specified expressions, they are returned in an implementation-dependent order.

Each `<expression>` can be the name or ordinal number of an output column (`SELECT` list item), or it can be an arbitrary expression formed from input-column values.

The ordinal number refers to the ordinal (left-to-right) position of the output column. This feature makes it possible to define an ordering on the basis of a column that does not have a unique name. This is never absolutely necessary because it is always possible to assign a name to an output column using the `AS` clause.

It is also possible to use arbitrary expressions in the `ORDER BY` clause, including columns that do not appear in the `SELECT` output list. Thus the following statement is valid:

```
SELECT name FROM distributors ORDER BY code;
```

A limitation of this feature is that an `ORDER BY` clause applying to the result of a `UNION`, `INTERSECT`, or `EXCEPT` clause may only specify an output column name or number, not an expression.

If an `ORDER BY` expression is a simple name that matches both an output column name and an input column name, `ORDER BY` will interpret it as the output column name. This is the opposite of the choice that `GROUP BY` will make in the same situation. This inconsistency is made to be compatible with the SQL standard.

Optionally one may add the key word `ASC` (ascending) or `DESC` (descending) after any expression in the `ORDER BY` clause. If not specified, `ASC` is assumed by default. Alternatively, a specific ordering operator name may be specified in the `USING` clause. `ASC` is usually equivalent to `USING <` and `DESC` is usually equivalent to `USING >`. (But the creator of a user-defined data type can define exactly what the default sort ordering is, and it might correspond to operators with other names.)

If `NULLS LAST` is specified, null values sort after all non-null values; if `NULLS FIRST` is specified, null values sort before all non-null values. If neither is specified, the default behavior is `NULLS LAST` when `ASC` is specified or implied, and `NULLS FIRST` when `DESC` is specified (thus, the default is to act as though nulls are larger than non-nulls). When `USING` is specified, the default nulls ordering depends upon whether the operator is a less-than or greater-than operator.

Note that ordering options apply only to the expression they follow; for example `ORDER BY x, y DESC` does not mean the same thing as `ORDER BY x DESC, y DESC`.

Character-string data is sorted according to the locale-specific collation order that was established when the database was created. You can override this at need by including a `COLLATE` clause in the expression, for example `ORDER BY mycolumn COLLATE "en_US"`.

Character-string data is sorted according to the collation that applies to the column being sorted. That can be overridden as needed by including a `COLLATE` clause in the expression, for example `ORDER BY mycolumn COLLATE "en_US"`. For information about defining collations, see CREATE COLLATION.

The LIMIT Clause

The `LIMIT` clause consists of two independent sub-clauses:

```
LIMIT {<count> | ALL}
OFFSET <start>
```

`<count>` specifies the maximum number of rows to return, while `<start>` specifies the number of rows to skip before starting to return rows. When both are specified, `<start>` rows are skipped before starting to count the `<count>` rows to be returned.

If the `<count>` expression evaluates to NULL, it is treated as `LIMIT ALL`, that is, no limit. If `<start>` evaluates to NULL, it is treated the same as `OFFSET 0`.

SQL:2008 introduced a different syntax to achieve the same result, which WarehousePG also supports. It is:

```
OFFSET <start> [ ROW | ROWS ]
    FETCH { FIRST | NEXT } [ <count> ] { ROW | ROWS } ONLY
```

In this syntax, the `<start>` or `<count>` value is required by the standard to be a literal constant, a parameter, or a variable name; as a WarehousePG extension, other expressions are allowed, but will generally need to be enclosed in parentheses to avoid ambiguity. If `<count>` is omitted in a `FETCH` clause, it defaults to `1`. `ROW` and `ROWS` as well as `FIRST` and `NEXT` are noise words that don't influence the effects of these clauses. According to the standard, the `OFFSET` clause must come before the `FETCH` clause if both are present; but WarehousePG allows either order.

When using `LIMIT`, it is a good idea to use an `ORDER BY` clause that constrains the result rows into a unique order. Otherwise you will get an unpredictable subset of the query's rows — you may be asking for the tenth through twentieth rows, but tenth through twentieth in what ordering? You don't know what ordering unless you specify `ORDER BY`.

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The query optimizer takes `LIMIT` into account when generating a query plan, so you are very likely to get different plans (yielding different row orders) depending on what you use for `LIMIT` and `OFFSET`. Thus, using different `LIMIT/OFFSET` values to select different subsets of a query result will give inconsistent results unless you enforce a predictable result ordering with `ORDER BY`. This is not a defect; it is an inherent consequence of the fact that SQL does not promise to deliver the results of a query in any particular order unless `ORDER BY` is used to constrain the order.

It is even possible for repeated executions of the same `LIMIT` query to return different subsets of the rows of a table, if there is not an `ORDER BY` to enforce selection of a deterministic subset. Again, this is not a bug; WarehousePG does not guarantee determinism of the results in such a case.

The Locking Clause

`FOR UPDATE`, `FOR NO KEY UPDATE`, `FOR SHARE`, and `FOR KEY SHARE` are *locking clauses*; they affect how `SELECT` locks rows as they are obtained from the table. The Global Deadlock Detector affects the locking used by `SELECT` queries that contain a locking clause (`FOR <lock_strength>`). The Global Deadlock Detector is enabled by setting the gp_enable_global_deadlock_detector configuration parameter to `on`. See Global Deadlock Detector in the *WarehousePG Administrator Guide* for information about the Global Deadlock Detector.

The locking clause has the general form:

```
FOR <lock_strength> [OF <table_name> [ , ... ] ] [ NOWAIT | SKIP LOCKED ]
```

`<lock_strength>` can be one of these values:

- `UPDATE` - Locks the table with an `EXCLUSIVE` lock.
- `NO KEY UPDATE` - Locks the table with an `EXCLUSIVE` lock.
- `SHARE` - Locks the table with a `ROW SHARE` lock.
- `KEY SHARE` - Locks the table with a `ROW SHARE` lock.

When the Global Deadlock Detector is deactivated (the default), WarehousePG uses the specified lock.

When the Global Deadlock Detector is enabled, a `ROW SHARE` lock is used to lock the table for simple `SELECT` queries that contain a locking clause, and the query plans contain a `lockrows` node. Simple `SELECT` queries that contain a locking clause fulfill all the following conditions:

- The locking clause is in the top level `SELECT` context.
- The `FROM` clause contains a single table that is not a view or an append optimized table.
- The `SELECT` command does not contain a set operation such as `UNION` or `INTERSECT`.
- The `SELECT` command does not contain a sub-query.

Otherwise, table locking for a `SELECT` query that contains a locking clause behaves as if the Global Deadlock Detector is deactivated.

> **Note** The Global Deadlock Detector also affects the locking used by `DELETE` and `UPDATE` operations. By default, WarehousePG acquires an `EXCLUSIVE` lock on tables for `DELETE` and `UPDATE` operations on heap tables. When the Global Deadlock Detector is enabled, the lock mode for `DELETE` and `UPDATE` operations on heap tables is `ROW EXCLUSIVE`.

For more information on each row-level lock mode, refer to Explicit Locking in the PostgreSQL documentation.

To prevent the operation from waiting for other transactions to commit, use either the `NOWAIT` option or the `SKIP LOCKED` option. With `NOWAIT`, the statement reports an error, rather than waiting, if a selected row cannot be locked immediately. With `SKIP LOCKED`, any selected rows that cannot be immediately locked are skipped. Skipping locked rows provides an inconsistent view of the data, so this is not suitable for general purpose work, but can be used to avoid lock contention with multiple consumers accessing a queue-like table. Note that `NOWAIT` and `SKIP LOCKED` apply only to the row-level lock(s) — the required `ROW SHARE` table-level lock is still taken in the ordinary way. You can use LOCK with the `NOWAIT` option first, if you need to acquire the table-level lock without waiting.

If specific tables are named in a locking clause, then only rows coming from those tables are locked; any other tables used in the `SELECT` are simply read as usual. A locking clause without a table list affects all tables used in the statement. If a locking clause is applied to a view or sub-query, it affects all tables used in the view or sub-query. However, these clauses do not apply to `WITH` queries referenced by the primary query. If you want row locking to occur within a `WITH` query, specify a locking clause within the `WITH` query.

Multiple locking clauses can be written if it is necessary to specify different locking behavior for different tables. If the same table is mentioned (or implicitly affected) by both more than one locking clause, then it is processed as if it was only specified by the strongest one. Similarly, a table is processed as `NOWAIT` if that is specified in any of the clauses affecting it. Otherwise, it is processed as `SKIP LOCKED` if that is specified in any of the clauses affecting it.

The locking clauses cannot be used in contexts where returned rows cannot be clearly identified with individual table rows; for example they cannot be used with aggregation.

When a locking clause appears at the top level of a `SELECT` query, the rows that are locked are exactly those that are returned by the query; in the case of a join query, the rows locked are those that contribute to returned join rows. In addition, rows that satisfied the query conditions as of the query snapshot will be locked, although they will not be returned if they were updated after the snapshot and no longer satisfy the query conditions. If a `LIMIT` is used, locking stops once enough rows have been returned to satisfy the limit (but note that rows skipped over by `OFFSET` will get locked). Similarly, if a locking clause is used in a cursor's query, only rows actually fetched or stepped past by the cursor will be locked.

When a locking clause appears in a sub-`SELECT`, the rows locked are those returned to the outer query by the sub-query. This might involve fewer rows than inspection of the sub-query alone would suggest, since conditions from the outer query might be used to optimize execution of the sub-query. For example,

```
SELECT * FROM (SELECT * FROM mytable FOR UPDATE) ss WHERE col1 = 5;
```

will lock only rows having `col1 = 5`, even though that condition is not textually within the sub-query.

It is possible for a `SELECT` command running at the `READ COMMITTED` transaction isolation level and using `ORDER BY` and a locking clause to return rows out of order. This is because `ORDER BY` is applied first. The command sorts the result, but might then block trying to obtain a lock on one or more of the rows. Once the `SELECT` unblocks, some of the ordering column values might have been modified, leading to those rows appearing to be out of order (though they are in order in terms of the original column values). This can be worked around at need by placing the `FOR UPDATE/SHARE` clause in a sub-query, for example

```
SELECT * FROM (SELECT * FROM mytable FOR UPDATE) ss ORDER BY column1;
```

Note that this will result in locking all rows of `mytable`, whereas `FOR UPDATE` at the top level would lock only the actually returned rows. This can make for a significant performance difference, particularly if the `ORDER BY` is combined with `LIMIT` or other restrictions. So this technique is recommended only if concurrent updates of the ordering columns are expected and a strictly sorted result is required.

At the `REPEATABLE READ` or `SERIALIZABLE` transaction isolation level this would cause a serialization failure (with a `SQLSTATE` of `40001`), so there is no possibility of receiving rows out of order under these isolation levels.

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The TABLE Command

The command

```
TABLE <name>
```

is equivalent to

```
SELECT * FROM <name>
```

It can be used as a top-level command or as a space-saving syntax variant in parts of complex queries. Only the `WITH`, `UNION`, `INTERSECT`, `EXCEPT`, `ORDER BY`, `LIMIT`, `OFFSET`, `FETCH`, and `FOR` locking clauses can be used with `TABLE`; the `WHERE` clause and any form of aggregation cannot be used.

Examples

To join the table `films` with the table `distributors`:

```
SELECT f.title, f.did, d.name, f.date_prod, f.kind
  FROM distributors d, JOIN films f USING (did);
```

To sum the column `length` of all films and group the results by `kind`:

```
SELECT kind, sum(length) AS total FROM films GROUP BY kind;
```

To sum the column `length` of all films, group the results by `kind`, and show those group totals that are less than 5 hours:

```
SELECT kind, sum(length) AS total FROM films GROUP BY kind
  HAVING sum(length) < interval '5 hours';
```

Calculate the subtotals and grand totals of all sales for movie `kind` and `distributor`.

```
SELECT kind, distributor, sum(prc*qty) FROM sales
GROUP BY ROLLUP(kind, distributor)
ORDER BY 1,2,3;
```

Calculate the rank of movie distributors based on total sales:

```
SELECT distributor, sum(prc*qty),
       rank() OVER (ORDER BY sum(prc*qty) DESC)
FROM sales
GROUP BY distributor ORDER BY 2 DESC;
```

The following two examples are identical ways of sorting the individual results according to the contents of the second column (`name`):

```
SELECT * FROM distributors ORDER BY name;
SELECT * FROM distributors ORDER BY 2;
```

The next example shows how to obtain the union of the tables `distributors` and `actors`, restricting the results to those that begin with the letter `W` in each table. Only distinct rows are wanted, so the key word `ALL` is omitted:

```
SELECT distributors.name
  FROM distributors
  WHERE distributors.name LIKE 'W%'
UNION
SELECT actors.name
  FROM actors
  WHERE actors.name LIKE 'W%';
```

This example shows how to use a function in the `FROM` clause, both with and without a column definition list:

```
CREATE FUNCTION distributors(int) RETURNS SETOF distributors
AS $$ SELECT * FROM distributors WHERE did = $1; $$ LANGUAGE
SQL;
SELECT * FROM distributors(111);

CREATE FUNCTION distributors_2(int) RETURNS SETOF record AS
$$ SELECT * FROM distributors WHERE did = $1; $$ LANGUAGE
SQL;
SELECT * FROM distributors_2(111) AS (dist_id int, dist_name text);
```

This example uses a function with an ordinality column added:

```
SELECT * FROM unnest(ARRAY['a','b','c','d','e','f']) WITH ORDINALITY;
```

This example uses a simple `WITH` clause:

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```
WITH test AS (
  SELECT random() as x FROM generate_series(1, 3)
  )
SELECT * FROM test
UNION ALL
SELECT * FROM test;
```

This example uses the `WITH` clause to display per-product sales totals in only the top sales regions.

```
WITH regional_sales AS
    SELECT region, SUM(amount) AS total_sales
    FROM orders
    GROUP BY region
  ), top_regions AS (
    SELECT region
    FROM regional_sales
    WHERE total_sales > (SELECT SUM(total_sales) FROM
       regional_sales)
  )
SELECT region, product, SUM(quantity) AS product_units,
   SUM(amount) AS product_sales
FROM orders
WHERE region IN (SELECT region FROM top_regions)
GROUP BY region, product;
```

The example could have been written without the `WITH` clause but would have required two levels of nested sub-`SELECT` statements.

This example uses the `WITH RECURSIVE` clause to find all subordinates (direct or indirect) of the employee Mary, and their level of indirectness, from a table that shows only direct subordinates:

```
WITH RECURSIVE employee_recursive(distance, employee_name, manager_name) AS (
    SELECT 1, employee_name, manager_name
    FROM employee
    WHERE manager_name = 'Mary'
  UNION ALL
    SELECT er.distance + 1, e.employee_name, e.manager_name
    FROM employee_recursive er, employee e
    WHERE er.employee_name = e.manager_name
  )
SELECT distance, employee_name FROM employee_recursive;
```

The typical form of a recursive query is an initial condition, followed by `UNION [ALL]`, followed by the recursive part of the query. Be sure that the recursive part of the query will eventually return no tuples, or else the query will loop indefinitely. See WITH Queries (Common Table Expressions)in the *WarehousePG Administrator Guide* for more examples.

This example uses `LATERAL` to apply a set-returning function `get_product_names()` for each row of the `manufacturers` table:

```
SELECT m.name AS mname, pname
  FROM manufacturers m, LATERAL get_product_names(m.id) pname;
```

Manufacturers not currently having any products would not appear in the result, since it is an inner join. If we wished to include the names of such manufacturers in the result, we could write the query as follows:

```
SELECT m.name AS mname, pname
  FROM manufacturers m LEFT JOIN LATERAL get_product_names(m.id) pname ON true;
```

Compatibility

The `SELECT` statement is compatible with the SQL standard, but there are some extensions and some missing features.

Omitted FROM Clauses

WarehousePG allows one to omit the `FROM` clause. It has a straightforward use to compute the results of simple expressions. For example:

```
SELECT 2+2;
```

Some other SQL databases cannot do this except by introducing a dummy one-row table from which to do the `SELECT`.

Note that if a `FROM` clause is not specified, the query cannot reference any database tables. For example, the following query is invalid:

```
SELECT distributors.* WHERE distributors.name = 'Westward';
```

In earlier releases, setting a server configuration parameter, `add_missing_from`, to true allowed WarehousePG to add an implicit entry to the query's `FROM` clause for each table referenced by the query. This is no longer allowed.

Empty SELECT Lists

The list of output expressions after `SELECT` can be empty, producing a zero-column result table. This is not valid syntax according to the SQL standard. WarehousePG allows it to be consistent with allowing zero-column tables. However, an empty list is not allowed when `DISTINCT` is used.

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Omitting the AS Key Word

In the SQL standard, the optional key word `AS` can be omitted before an output column name whenever the new column name is a valid column name (that is, not the same as any reserved keyword). WarehousePG is slightly more restrictive: `AS` is required if the new column name matches any keyword at all, reserved or not. Recommended practice is to use `AS` or double-quote output column names, to prevent any possible conflict against future keyword additions.

In `FROM` items, both the standard and WarehousePG allow `AS` to be omitted before an alias that is an unreserved keyword. But this is impractical for output column names, because of syntactic ambiguities.

ONLY and Inheritance

The SQL standard requires parentheses around the table name when writing `ONLY`, for example:

```
SELECT * FROM ONLY (tab1), ONLY (tab2) WHERE ...
```

WarehousePG considers these parentheses to be optional.

WarehousePG allows a trailing `*` to be written to explicitly specify the non-`ONLY` behavior of including child tables. The standard does not allow this.

Note: The above points apply equally to all SQL commands supporting the `ONLY` option.

Function Calls in FROM

WarehousePG allows you to write a function call directly as a member of the `FROM` list. In the SQL standard it would be necessary to wrap such a function call in a sub-`SELECT`; that is, the syntax `FROM func(...) alias` is approximately equivalent to `FROM LATERAL (SELECT func(...)) alias`. Note that `LATERAL` is considered to be implicit; this is because the standard requires `LATERAL` semantics for an `UNNEST()` item in `FROM`. WarehousePG treats `UNNEST()` the same as other set-returning functions.

Namespace Available to GROUP BY and ORDER BY

In the SQL-92 standard, an `ORDER BY` clause may only use output column names or numbers, while a `GROUP BY` clause may only use expressions based on input column names. WarehousePG extends each of these clauses to allow the other choice as well (but it uses the standard's interpretation if there is ambiguity). WarehousePG also allows both clauses to specify arbitrary expressions. Note that names appearing in an expression are always taken as input-column names, not as output column names.

SQL:1999 and later use a slightly different definition which is not entirely upward compatible with SQL-92. In most cases, however, WarehousePG interprets an `ORDER BY` or `GROUP BY` expression the same way SQL:1999 does.

Functional Dependencies

WarehousePG recognizes functional dependency (allowing columns to be omitted from `GROUP BY`) only when a table's primary key is included in the `GROUP BY` list. The SQL standard specifies additional conditions that should be recognized.

LIMIT and OFFSET

The clauses `LIMIT` and `OFFSET` are WarehousePG-specific syntax, also used by MySQL. The SQL:2008 standard has introduced the clauses `OFFSET .. FETCH {FIRST|NEXT} ...` for the same functionality, as shown above in LIMIT Clause. This syntax is also used by IBM DB2. (Applications for Oracle frequently use a workaround involving the automatically generated `rownum` column, which is not available in WarehousePG, to implement the effects of these clauses.)

FOR NO KEY UPDATE, FOR UPDATE, FOR SHARE, and FOR KEY SHARE

Although `FOR UPDATE` appears in the SQL standard, the standard allows it only as an option of `DECLARE CURSOR`. WarehousePG allows it in any `SELECT` query as well as in sub-`SELECT`s, but this is an extension. The `FOR NO KEY UPDATE`, `FOR SHARE`, and `FOR KEY SHARE` variants, as well as the `NOWAIT` and `SKIP LOCKED` options, do not appear in the standard.

Data-Modifying Statements in WITH

WarehousePG allows `INSERT`, `UPDATE`, and `DELETE` to be used as `WITH` queries. This is not found in the SQL standard.

Nonstandard Clauses

The clause `DISTINCT ON` is not defined in the SQL standard.

`ROWS FROM( ... )` is an extension of the SQL standard.

The `MATERIALIZED` and `NOT MATERIALIZED` options of `WITH` are extensions of the SQL standard.

Limited Use of STABLE and VOLATILE Functions

To prevent data from becoming out-of-sync across the segments in WarehousePG, any function classified as `STABLE` or `VOLATILE` cannot be run at the segment database level if it contains SQL or modifies the database in any way. See CREATE FUNCTION for more information.

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See Also

EXPLAIN

Parent topic: SQL Commands

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7.1.164 SELECT INTO

Defines a new table from the results of a query.

Synopsis

```
[ WITH [ RECURSIVE ] <with_query> [, ...] ]
SELECT [ALL | DISTINCT [ON ( <expression> [, ...] )]]
    * | <expression> [ [AS] <output_name> ] [, ...]
    INTO [TEMPORARY | TEMP | UNLOGGED ] [TABLE] <new_table>
    [FROM <from_item> [, ...]]
    [WHERE <condition>]
    [GROUP BY <expression> [, ...]]
    [HAVING <condition> [, ...]]
    [WINDOW <window_name> AS ( <window_definition> ) [, ...]]
    [{UNION | INTERSECT | EXCEPT} [ALL | DISTINCT ] <select>]
    [ORDER BY <expression> [ASC | DESC | USING <operator>] [NULLS {FIRST | LAST}] [, ...]]
    [LIMIT {<count> | ALL}]
    [OFFSET <start> [ ROW | ROWS ] ]
    [FETCH { FIRST | NEXT } [ <count> ] { ROW | ROWS } ONLY ]
    [FOR {UPDATE | SHARE} [OF <table_name> [, ...]] [NOWAIT] [...]]
```

Description

`SELECT INTO` creates a new table and fills it with data computed by a query. The data is not returned to the client, as it is with a normal `SELECT`. The new table's columns have the names and data types associated with the output columns of the `SELECT`.

Parameters

TEMPORARY TEMP If specified, the table is created as a temporary table. Refer to CREATE TABLE for details.

UNLOGGED If specified, the table is created as an unlogged table. Refer to CREATE TABLE for details.

new_table The name (optionally schema-qualified) of the table to be created.

All other parameters for `SELECT INTO` are described in detail on the SELECT reference page.

Notes

CREATE TABLE AS is functionally similar to `SELECT INTO`. `CREATE TABLE AS` is the recommended syntax, since this form of `SELECT INTO` is not available in ECPG or PL/pgSQL, because they interpret the `INTO` clause differently. Also, `CREATE TABLE AS` offers a superset of the functionality provided by `SELECT INTO`.

In contrast to `CREATE TABLE AS`, `SELECT INTO` does not allow specifying properties like a table's access method with `USING <method>` or the table's tablespace with `TABLESPACE <tablespace_name>`. Use CREATE TABLE AS if necessary. Therefore, the default table access method is chosen for the new table. See default_table_access_method for more information.

Examples

Create a new table `films_recent` consisting only of recent entries from the table `films`:

```
SELECT * INTO films_recent FROM films WHERE date_prod >= '2016-01-01';
```

Compatibility

The SQL standard uses `SELECT INTO` to represent selecting values into scalar variables of a host program, rather than creating a new table. The WarehousePG usage of `SELECT INTO` to represent table creation is historical. It is best to use CREATE TABLE AS for this purpose in new applications.

See Also

SELECT, CREATE TABLE AS

Parent topic: SQL Commands

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7.1.165 SET

Changes the value of a run-time WarehousePG configuration parameter.

Synopsis

```
SET [ SESSION | LOCAL ] <configuration_parameter> { TO | = } { <value> | '<value>' | DEFAULT }

SET [SESSION | LOCAL] TIME ZONE { <value> | '<value>' |  LOCAL | DEFAULT }
```

Description

The `SET` command changes server configuration parameters. Any configuration parameter classified as a session parameter can be changed on-the-fly with `SET`. (Some require superuser privileges to change, and others cannot be changed after server or session start.) `SET` affects only the value used by the current session.

If `SET` or `SET SESSION` is issued within a transaction that is later cancelled, the effects of the `SET` command disappear when the transaction is rolled back. Once the surrounding transaction is committed, the effects will persist until the end of the session, unless overridden by another `SET`.

The effects of `SET LOCAL` last only till the end of the current transaction, whether committed or not. A special case is `SET` followed by `SET LOCAL` within a single transaction: the `SET LOCAL` value will be seen until the end of the transaction, but afterwards (if the transaction is committed) the `SET` value will take effect.

The effects of `SET` or `SET LOCAL` are also canceled by rolling back to a savepoint that is earlier than the command.

If `SET LOCAL` is used within a function that includes a `SET` option for the same configuration parameter (see CREATE FUNCTION), the effects of the `SET LOCAL` command disappear at function exit; the value in effect when the function was called is restored anyway. This allows `SET LOCAL` to be used for dynamic or repeated changes of a parameter within a function, while retaining the convenience of using the `SET` option to save and restore the caller's value. Note that a regular `SET` command overrides any surrounding function's `SET` option; its effects persist unless rolled back.

See Server Configuration Parameters for information about server parameters.

Parameters

SESSION Specifies that the command takes effect for the current session. This is the default if neither `SESSION` nor `LOCAL` appears.

LOCAL Specifies that the command takes effect for only the current transaction. After `COMMIT` or `ROLLBACK`, the session-level setting takes effect again. Issuing this outside of a transaction block emits a warning and otherwise has no effect.

configuration_parameter The name of a settable WarehousePG run-time configuration parameter. Only parameters classified as *session* can be changed with `SET`. See Server Configuration Parameters for details.

value New value of the parameter. Values can be specified as string constants, identifiers, numbers, or comma-separated lists of these, as appropriate for the particular parameter. `DEFAULT` can be used to specify resetting the parameter to its default value (that is, whatever value it would have had if no `SET` had been issued in the current session). If specifying memory sizing or time units, enclose the value in single quotes.

There are a few configuration parameters that can only be adjusted using the `SET` command or that have a special syntax:

SCHEMA `SET SCHEMA '<value>'` is an alias for `SET <search_path> TO <value>`. Only one schema may be specified using this syntax.

NAMES `SET NAMES <value>` is an alias for `SET client_encoding TO <value>`.

SEED Sets the internal seed for the random number generator (the function `random()`). Allowed values are floating-point numbers between -1 and 1 inclusive.

You can also set the seed by invoking the `setseed()` function:

```
```
SELECT setseed(value);
```
```

TIME ZONE `SET TIME ZONE <value>` is an alias for `SET timezone TO <value>`. The syntax `SET TIME ZONE` allows special syntax for the time zone specification. Examples of valid values follow:

```
- `'PST8PDT'`
- `'Europe/Rome'`
- `-7` \(time zone 7 hours west from UTC\)
- `INTERVAL '-08:00' HOUR TO MINUTE` \(time zone 8 hours west from UTC\).

LOCAL
DEFAULT
Set the time zone to your local time zone \(that is, server's default value of timezone\).

See the [Time Zones](https://www.postgresql.org/docs/12/datatype-datetime.html#DATATYPE-TIMEZONES) section of the PostgreSQL documentation for more information
about time zones in WarehousePG.
```

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Examples

Set the schema search path:

```
SET search_path TO my_schema, public;
```

Increase the segment host memory per query to 200 MB:

```
SET statement_mem TO '200MB';
```

Set the style of date to traditional POSTGRES with "day before month" input convention:

```
SET datestyle TO postgres, dmy;
```

Set the time zone for San Mateo, California (Pacific Time):

```
SET TIME ZONE 'PST8PDT';
```

Set the time zone for Italy:

```
SET TIME ZONE 'Europe/Rome';
```

Compatibility

`SET TIME ZONE` extends syntax defined in the SQL standard. The standard allows only numeric time zone offsets while WarehousePG allows more flexible time-zone specifications. All other `SET` features are WarehousePG extensions.

See Also

RESET, SHOW

Parent topic: SQL Commands

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7.1.166 SET CONSTRAINTS

Sets constraint check timing for the current transaction.

> **Note** Referential integrity syntax (foreign key constraints) is accepted but not enforced.

Synopsis

```
SET CONSTRAINTS { ALL | <name> [, ...] } { DEFERRED | IMMEDIATE }
```

Description

`SET CONSTRAINTS` sets the behavior of constraint checking within the current transaction. `IMMEDIATE` constraints are checked at the end of each statement. `DEFERRED` constraints are not checked until transaction commit. Each constraint has its own `IMMEDIATE` or `DEFERRED` mode.

Upon creation, a constraint is given one of three characteristics: `DEFERRABLE INITIALLY DEFERRED`, `DEFERRABLE INITIALLY IMMEDIATE`, or `NOT DEFERRABLE`. The third class is always `IMMEDIATE` and is not affected by the `SET CONSTRAINTS` command. The first two classes start every transaction in the indicated mode, but their behavior can be changed within a transaction by `SET CONSTRAINTS`.

`SET CONSTRAINTS` with a list of constraint names changes the mode of just those constraints (which must all be deferrable). Each constraint name can be schema-qualified. The current schema search path is used to find the first matching name if no schema name is specified. `SET CONSTRAINTS ALL` changes the mode of all deferrable constraints.

When `SET CONSTRAINTS` changes the mode of a constraint from `DEFERRED` to `IMMEDIATE`, the new mode takes effect retroactively: any outstanding data modifications that would have been checked at the end of the transaction are instead checked during the execution of the `SET CONSTRAINTS` command. If any such constraint is violated, the `SET CONSTRAINTS` fails (and does not change the constraint mode). Thus, `SET CONSTRAINTS` can be used to force checking of constraints to occur at a specific point in a transaction.

Currently, only `UNIQUE`, `PRIMARY KEY`, `REFERENCES` (foreign key), and `EXCLUDE` constraints are affected by this setting. `NOT NULL` and `CHECK` constraints are always checked immediately when a row is inserted or modified (*not* at the end of the statement). Uniqueness and exclusion constraints that have not been declared `DEFERRABLE` are also checked immediately.

The firing of triggers that are declared as "constraint triggers" is also controlled by this setting — they fire at the same time that the associated constraint should be checked.

Notes

Because WarehousePG does not require constraint names to be unique within a schema (but only per-table), it is possible that there is more than one match for a specified constraint name. In this case `SET CONSTRAINTS` will act on all matches. For a non-schema-qualified name, once a match or matches have been found in some schema in the search path, schemas appearing later in the path are not searched.

This command only alters the behavior of constraints within the current transaction. Issuing this outside of a transaction block emits a warning and otherwise has no effect.

Compatibility

This command complies with the behavior defined in the SQL standard, except for the limitation that, in WarehousePG, it does not apply to `NOT NULL` and `CHECK` constraints. Also, WarehousePG checks non-deferrable uniqueness constraints immediately, not at end of statement as the standard would suggest.

Parent topic: SQL Commands

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7.1.167 SET ROLE

Sets the current role identifier of the current session.

Synopsis

```
SET [SESSION | LOCAL] ROLE <rolename>

SET [SESSION | LOCAL] ROLE NONE

RESET ROLE
```

Description

This command sets the current role identifier of the current SQL-session context to be rolename. The role name may be written as either an identifier or a string literal. After `SET ROLE`, permissions checking for SQL commands is carried out as though the named role were the one that had logged in originally.

The specified rolename must be a role that the current session user is a member of. If the session user is a superuser, any role can be selected.

The `NONE` and `RESET` forms reset the current role identifier to be the current session role identifier. These forms may be run by any user.

Parameters

SESSION Specifies that the command takes effect for the current session. This is the default.

LOCAL Specifies that the command takes effect for only the current transaction. After `COMMIT` or `ROLLBACK`, the session-level setting takes effect again. Note that `SET LOCAL` will appear to have no effect if it is run outside of a transaction.

rolename The name of a role to use for permissions checking in this session.

NONE RESET Reset the current role identifier to be the current session role identifier (that of the role used to log in).

Notes

Using this command, it is possible to either add privileges or restrict privileges. If the session user role has the `INHERITS` attribute, then it automatically has all the privileges of every role that it could `SET ROLE` to; in this case `SET ROLE` effectively drops all the privileges assigned directly to the session user and to the other roles it is a member of, leaving only the privileges available to the named role. On the other hand, if the session user role has the `NOINHERITS` attribute, `SET ROLE` drops the privileges assigned directly to the session user and instead acquires the privileges available to the named role.

In particular, when a superuser chooses to `SET ROLE` to a non-superuser role, they lose their superuser privileges.

`SET ROLE` has effects comparable to `SET SESSION AUTHORIZATION`, but the privilege checks involved are quite different. Also, `SET SESSION AUTHORIZATION` determines which roles are allowable for later `SET ROLE` commands, whereas changing roles with `SET ROLE` does not change the set of roles allowed to a later `SET ROLE`.

`SET ROLE` does not process session variables specified by the role's `ALTER ROLE` settings; the session variables are only processed during login.

Examples

```
SELECT SESSION_USER, CURRENT_USER;
 session_user | current_user
--------------+--------------
 peter        | peter

SET ROLE 'paul';

SELECT SESSION_USER, CURRENT_USER;
 session_user | current_user
--------------+--------------
 peter        | paul
```

Compatibility

WarehousePG allows identifier syntax (rolename), while the SQL standard requires the role name to be written as a string literal. SQL does not allow this command during a transaction; WarehousePG does not make this restriction. The `SESSION` and `LOCAL` modifiers are a WarehousePG extension, as is the `RESET` syntax.

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See Also

SET SESSION AUTHORIZATION

Parent topic: SQL Commands

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7.1.168 SET SESSION AUTHORIZATION

Sets the session role identifier and the current role identifier of the current session.

Synopsis

```
SET [SESSION | LOCAL] SESSION AUTHORIZATION <rolename>

SET [SESSION | LOCAL] SESSION AUTHORIZATION DEFAULT

RESET SESSION AUTHORIZATION
```

Description

This command sets the session role identifier and the current role identifier of the current SQL-session context to be rolename. The role name may be written as either an identifier or a string literal. Using this command, it is possible, for example, to temporarily become an unprivileged user and later switch back to being a superuser.

The session role identifier is initially set to be the (possibly authenticated) role name provided by the client. The current role identifier is normally equal to the session user identifier, but may change temporarily in the context of `setuid` functions and similar mechanisms; it can also be changed by SET ROLE. The current user identifier is relevant for permission checking.

The session user identifier may be changed only if the initial session user (the authenticated user) had the superuser privilege. Otherwise, the command is accepted only if it specifies the authenticated user name.

The `DEFAULT` and `RESET` forms reset the session and current user identifiers to be the originally authenticated user name. These forms may be run by any user.

Parameters

SESSION Specifies that the command takes effect for the current session. This is the default.

LOCAL Specifies that the command takes effect for only the current transaction. After `COMMIT` or `ROLLBACK`, the session-level setting takes effect again. Note that `SET LOCAL` will appear to have no effect if it is run outside of a transaction.

rolename The name of the role to assume.

NONE RESET Reset the session and current role identifiers to be that of the role used to log in.

Examples

```
SELECT SESSION_USER, CURRENT_USER;
 session_user | current_user
--------------+--------------
 peter        | peter

SET SESSION AUTHORIZATION 'paul';

SELECT SESSION_USER, CURRENT_USER;
 session_user | current_user
--------------+--------------
 paul         | paul
```

Compatibility

The SQL standard allows some other expressions to appear in place of the literal rolename, but these options are not important in practice. WarehousePG allows identifier syntax (rolename), which SQL does not. SQL does not allow this command during a transaction; WarehousePG does not make this restriction. The `SESSION` and `LOCAL` modifiers are a WarehousePG extension, as is the `RESET` syntax.

See Also

SET ROLE

Parent topic: SQL Commands

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7.1.169 SET TRANSACTION

Sets the characteristics of the current transaction.

Synopsis

```
SET TRANSACTION <transaction_mode> [, ...]
SET TRANSACTION SNAPSHOT <snapshot_id>
SET SESSION CHARACTERISTICS AS TRANSACTION <transaction_mode> [, ...]
     [READ ONLY | READ WRITE]
     [NOT] DEFERRABLE

where <transaction_mode> is one of:

    ISOLATION LEVEL {SERIALIZABLE | REPEATABLE READ | READ COMMITTED | READ UNCOMMITTED}
    READ WRITE | READ ONLY
    [NOT] DEFERRABLE

and <snapshot_id> is the id of the existing transaction whose snapshot you want this transaction to run with.
```

Description

The `SET TRANSACTION` command sets the characteristics of the current transaction. It has no effect on any subsequent transactions. `SET SESSION CHARACTERISTICS` sets the default transaction characteristics for subsequent transactions of a session. These defaults can be overridden by `SET TRANSACTION` for an individual transaction.

The available transaction characteristics are the transaction isolation level, the transaction access mode (read/write or read-only), and the deferrable mode. In addition, a snapshot can be selected, though only for the current transaction, not as a session default.

> **Note** Deferrable transactions require the transaction to be serializable. WarehousePG does not support serializable transactions, so including the `DEFERRABLE` clause has no effect.

The isolation level of a transaction determines what data the transaction can see when other transactions are running concurrently.

- **READ COMMITTED** — A statement can only see rows committed before it began. This is the default.
- **REPEATABLE READ** — All statements in the current transaction can only see rows committed before the first query or data-modification statement run in the transaction.

The SQL standard defines two additional levels, `READ UNCOMMITTED` and `SERIALIZABLE`. In WarehousePG, `READ UNCOMMITTED` is treated as `READ COMMITTED`. If you specify `SERIALIZABLE`, WarehousePG falls back to `REPEATABLE READ`.

The transaction isolation level cannot be changed after the first query or data-modification statement (`SELECT`, `INSERT`, `DELETE`, `UPDATE`, `FETCH`, or `COPY`) of a transaction has been run.

The transaction access mode determines whether the transaction is read/write or read-only. Read/write is the default. When a transaction is read-only, the following SQL commands are disallowed: `INSERT`, `UPDATE`, `DELETE`, and `COPY FROM` if the table they would write to is not a temporary table; all `CREATE`, `ALTER`, and `DROP` commands; `COMMENT`, `GRANT`, `REVOKE`, `TRUNCATE`; and `EXPLAIN ANALYZE` and `EXECUTE` if the command they would run is among those listed. This is a high-level notion of read-only that does not prevent all writes to disk.

The `DEFERRABLE` transaction property has no effect unless the transaction is also `SERIALIZABLE` and `READ ONLY`. When all of these properties are set on a transaction, the transaction may block when first acquiring its snapshot, after which it is able to run without the normal overhead of a `SERIALIZABLE` transaction and without any risk of contributing to or being cancelled by a serialization failure. This mode is well suited for long-running reports or backups. *Because WarehousePG does not support serializable transactions, the `DEFERRABLE` transaction property has no effect in WarehousePG.*

The `SET TRANSACTION SNAPSHOT` command allows a new transaction to run with the same snapshot as an existing transaction. The pre-existing transaction must have exported its snapshot with the `pg_export_snapshot()` function. That function returns a snapshot identifier, which must be given to `SET TRANSACTION SNAPSHOT` to specify which snapshot is to be imported. The identifier must be written as a string literal in this command, for example `'000003A1-1'`. `SET TRANSACTION SNAPSHOT` can only be executed at the start of a transaction, before the first query or data-modification statement (`SELECT`, `INSERT`, `DELETE`, `UPDATE`, `FETCH`, or `COPY`) of the transaction. Furthermore, the transaction must already be set to `SERIALIZABLE` or `REPEATABLE READ` isolation level (otherwise, the snapshot would be discarded immediately, since `READ COMMITTED` mode takes a new snapshot for each command). If the importing transaction uses `SERIALIZABLE` isolation level, then the transaction that exported the snapshot must also use that isolation level. Also, a non-read-only serializable transaction cannot import a snapshot from a read-only transaction.

Notes

If `SET TRANSACTION` is run without a prior START TRANSACTION or BEGIN, it emits a warning and otherwise has no effect.

It is possible to dispense with `SET TRANSACTION` by instead specifying the desired transaction_modes in `BEGIN` or `START TRANSACTION`. But that option is not available for `SET TRANSACTION SNAPSHOT`.

The session default transaction modes can also be set or examined via the configuration parametersdefault_transaction_isolation, default_transaction_read_only, and default_transaction_deferrable. (In fact `SET SESSION CHARACTERISTICS` is just a verbose equivalent for setting these variables with `SET`.) This means the defaults can be set in the configuration file, via `ALTER DATABASE`, etc.

The current transaction's modes can similarly be set or examined via the configuration parameterstransaction_isolation, transaction_read_only, and transaction_deferrable. Setting one of these parameters acts the same as the corresponding `SET TRANSACTION` option, with the same restrictions on when it can be done. However, these parameters cannot be set in the configuration file, or from any source other than live SQL.

Examples

To begin a new transaction with the same snapshot as an already existing transaction, first export the snapshot from the existing transaction. That will return the snapshot identifier, for example:

```
BEGIN TRANSACTION ISOLATION LEVEL REPEATABLE READ;
SELECT pg_export_snapshot();
 pg_export_snapshot
---------------------
 00000003-0000001B-1
(1 row)
```

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Then give the snapshot identifier in a `SET TRANSACTION SNAPSHOT` command at the beginning of the newly opened transaction:

```
BEGIN TRANSACTION ISOLATION LEVEL REPEATABLE READ;
SET TRANSACTION SNAPSHOT '00000003-0000001B-1';
```

Compatibility

These commands are defined in the SQL standard, except for the `DEFERRABLE` transaction mode and the `SET TRANSACTION SNAPSHOT` form, which are WarehousePG extensions.

`SERIALIZABLE` is the default transaction isolation level in the standard. In WarehousePG, the default is `READ COMMITTED`. Due to lack of predicate locking, WarehousePG does not fully support the `SERIALIZABLE` level, so it falls back to the `REPEATABLE READ` level when `SERIALIZABLE` is specified. Essentially, a predicate-locking system prevents phantom reads by restricting what is written, whereas a multi-version concurrency control model (MVCC) as used in WarehousePG prevents them by restricting what is read.

In the SQL standard, there is one other transaction characteristic that can be set with these commands: the size of the diagnostics area. This concept is specific to embedded SQL, and therefore is not implemented in the WarehousePG server.

The SQL standard requires commas between successive transaction_modes, but for historical reasons WarehousePG allows the commas to be omitted.

See Also

BEGIN

Parent topic: SQL Commands

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7.1.170 SHOW

Shows the value of a run-time system configuration parameter.

Synopsis

```
SHOW <name>

SHOW ALL
```

Description

`SHOW` displays the current settings of WarehousePG run-time system configuration parameters. You can set these parameters with the `SET` statement, by editing the `postgresql.conf` configuration file of the WarehousePG coordinator, through the `PGOPTIONS` environment variable (when using libpq or a libpq-based application), or through command-line flags when starting the WarehousePG server.

Parameters

name The name of a run-time system configuration parameter.

Some parameters viewable by `SHOW` are read-only — you can view their values but not set them:

```
SERVER_VERSION
Shows the version number of the WarehousePG server.

SERVER_ENCODING
Shows the server-side character set encoding. You can show, but not set, this parameter because the encoding is determined at database creation time.

LC_COLLATE
Shows the database's locale setting for collation (text ordering). You can show, but not set, this parameter because the setting is determined at database
creation time.

LC_CTYPE
Shows the database's locale setting for character classification; You can show, but not set, this parameter because the setting is determined at database creation
time.

IS_SUPERUSER
True if the current role has superuser privileges.
```

ALL Shows the current value of all configuration parameters, with descriptions.

Notes

The function `current_setting()` produces equivalent output; see System Administration Functions in the PostgreSQL documentation. Also, the pg_settings system view produces the same information.

Examples

Show the current setting of the parameter `DateStyle`:

```
SHOW DateStyle;
 DateStyle
-----------
 ISO, MDY
(1 row)
```

Show the current setting of the parameter `row_security`:

```
SHOW row_security;
 row_security
--------------
 on
(1 row)
```

Show the current setting of all parameters:

```
SHOW ALL;
       name       | setting |                  description
------------------+---------+-----------------------------------------------------
 application_name | psql    | Sets the application name to be reported in sta...

 ...

 xmlbinary        | base64  | Sets how binary values are to be encoded in XML.
 xmloption        | content | Sets whether XML data in implicit parsing and s...
(473 rows)
```

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Compatibility

The `SHOW` command is a WarehousePG extension.

See Also

SET, RESET

Parent topic: SQL Commands

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7.1.171 START TRANSACTION

Starts a transaction block.

Synopsis

```
START TRANSACTION [<transaction_mode>] [, ...]

where <transaction_mode> is one of:

   ISOLATION LEVEL {SERIALIZABLE | REPEATABLE READ | READ COMMITTED | READ UNCOMMITTED}
   READ WRITE | READ ONLY
   [NOT] DEFERRABLE
```

Description

`START TRANSACTION` begins a new transaction block. If the isolation level, read/write mode, or deferrable mode is specified, the new transaction has those characteristics, as if SET TRANSACTION was run. This is the same as the BEGIN command.

Parameters

Refer to SET TRANSACTION for information on the meaning of the parameters to this statement.

Compatibility

In the standard, it is not necessary to issue `START TRANSACTION` to start a transaction block: any SQL command implicitly begins a block. WarehousePG's behavior can be seen as implicitly issuing a `COMMIT` after each command that does not follow `START TRANSACTION` (or `BEGIN`), and it is therefore often called 'autocommit'. Other relational database systems may offer an autocommit feature as a convenience.

The `DEFERRABLE` transaction_mode is a WarehousePG language extension.

The SQL standard requires commas between successive transaction_modes, but for historical reasons WarehousePG allows the commas to be omitted.

See also the compatibility section of SET TRANSACTION.

See Also

BEGIN, COMMIT, ROLLBACK, SAVEPOINT, SET TRANSACTION

Parent topic: SQL Commands

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7.1.172 TRUNCATE

Empties a table or set of tables of all rows.

> **Note** WarehousePG does not enforce referential integrity syntax (foreign key constraints). `TRUNCATE` truncates a table that is referenced in a foreign key constraint even if the `CASCADE` option is omitted.

Synopsis

```
TRUNCATE [TABLE] [ONLY] <name> [ * ] [, ...]
    [ RESTART IDENTITY | CONTINUE IDENTITY ] [CASCADE | RESTRICT]
```

Description

`TRUNCATE` quickly removes all rows from a table or set of tables. It has the same effect as an unqualified DELETE on each table, but since it does not actually scan the tables it is faster. Furthermore, it reclaims disk space immediately, rather than requiring a subsequent VACUUM operation. This is most useful on large tables.

You must have the `TRUNCATE` privilege on the table to truncate it.

Parameters

name The name (optionally schema-qualified) of a table to truncate. If `ONLY` is specified before the table name, only that table is truncated. If `ONLY` is not specified, the table and all its descendant tables (if any) are truncated. Optionally, you can specify `*` after the table name to explicitly indicate that descendant tables are included.

RESTART IDENTITY Automatically restart sequences owned by columns of the truncated table(s).

CONTINUE IDENTITY Do not change the values of sequences. This is the default.

CASCADE Because this key word applies to foreign key references (which are not supported in WarehousePG) it has no effect.

RESTRICT Because this key word applies to foreign key references (which are not supported in WarehousePG) it has no effect.

Notes

`TRUNCATE` acquires an `ACCESS EXCLUSIVE` lock on each table that it operates on, which blocks all other concurrent operations on the table. When `RESTART IDENTITY` is specified, any sequences that are to be restarted are likewise locked exclusively. If you require concurrent access to a table, use the `DELETE` command instead.

`TRUNCATE` will not fire any user-defined `ON DELETE` triggers that might exist for the tables.

`TRUNCATE` will not truncate any tables that inherit from the named table. Only the named table is truncated, not its child tables.

`TRUNCATE` is not MVCC-safe. After truncation, the table will appear empty to concurrent transactions, if they are using a snapshot taken before the truncation occurred.

`TRUNCATE` is transaction-safe with respect to the data in the tables: the truncation will be safely rolled back if the surrounding transaction does not commit.

When `RESTART IDENTITY` is specified, the implied `ALTER SEQUENCE RESTART` operations are also done transactionally; that is, they will be rolled back if the surrounding transaction does not commit. Be aware that if any additional sequence operations are done on the restarted sequences before the transaction rolls back, the effects of these operations on the sequences will be rolled back.

`TRUNCATE` is not currently supported for foreign tables. This implies that if a specified table has any descendant tables that are foreign, the command will fail.

Examples

Empty the tables `films` and `distributors`:

```
TRUNCATE films, distributors;
```

The same, and also reset any associated sequence generators:

```
TRUNCATE films, distributors RESTART IDENTITY;
```

Compatibility

The SQL:2008 standard includes a `TRUNCATE` command with the syntax `TRUNCATE TABLE tablename`. The clauses `CONTINUE IDENTITY` / `RESTART IDENTITY` also appear in that standard, but have slightly different though related meanings. Some of the concurrency behavior of this command is left implementation-defined by the standard, so the above notes should be considered and compared with other implementations if necessary.

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See Also

DELETE

Parent topic: SQL Commands

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7.1.173 UNLISTEN

Stops listening for a notification.

Synopsis

```
UNLISTEN { <channel> | * }
```

Description

`UNLISTEN` is used to remove an existing registration for `NOTIFY` events. `UNLISTEN` cancels any existing registration of the current WarehousePG session as a listener on the notification channel named channel. The special wildcard `*` cancels all listener registrations for the current session.

NOTIFY contains a more extensive discussion of the use of `LISTEN` and `NOTIFY`.

Parameters

channel The name of a notification channel (any identifier).

- All current listen registrations for this session are cleared.

Notes

You can unlisten something you were not listening for; no warning or error will appear.

At the end of each session, `UNLISTEN *` is automatically executed.

A transaction that has executed `UNLISTEN` cannot be prepared for two-phase commit.

Examples

To make a registration:

```
LISTEN virtual;
NOTIFY virtual;
Asynchronous notification "virtual" received from server process with PID 8448.
```

Once `UNLISTEN` has been executed, further `NOTIFY` messages will be ignored:

```
UNLISTEN virtual;
NOTIFY virtual;
-- no NOTIFY event is received
```

Compatibility

There is no `UNLISTEN` statement in the SQL standard.

See Also

LISTEN, NOTIFY

Parent topic: SQL Commands

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7.1.174 UPDATE

Updates rows of a table.

Synopsis

```
[ WITH [ RECURSIVE ] <with_query> [, ...] ]
UPDATE [ ONLY ] <table_name> [ [ AS ] <alias> ]
   SET { <column_name> = { <expression> | DEFAULT } |
       ( <column_name> [, ...] ) = [ ROW ] ( { <expression> | DEFAULT } [, ...] ) |
       ( <column_name> [, ...] ) = ( <sub-SELECT> )
       } [, ...]
   [ FROM <from_item> [, ...] ]
   [ WHERE <condition> | WHERE CURRENT OF <cursor_name> ]
   [ RETURNING * | <output_expression> [ [AS] <output_name> ] [, ...] ]
```

Description

`UPDATE` changes the values of the specified columns in all rows that satisfy the condition. Only the columns to be modified need be mentioned in the `SET` clause; columns not explicitly modified retain their previous values.

There are two ways to modify a table using information contained in other tables in the database: using sub-selects, or specifying additional tables in the `FROM` clause. Which technique is more appropriate depends on the specific circumstances.

The optional `RETURNING` clause causes `UPDATE` to compute and return value(s) based on each row actually updated. WarehousePG can compute any expression using the table's columns, and/or columns of other tables mentioned in `FROM`. The new (post-update) values of the table's columns are used. The syntax of the `RETURNING` list is identical to that of the output list of `SELECT`.

You must have the `UPDATE` privilege on the table, or at least on the column(s) that are listed to be updated. You must also have the `SELECT` privilege on any column whose values are read in the expressions or condition.

> **Note** As the default, WarehousePG acquires an `EXCLUSIVE` lock on tables for `UPDATE` operations on heap tables. When the Global Deadlock Detector is enabled, the lock mode for `UPDATE` operations on heap tables is `ROW EXCLUSIVE`. See Global Deadlock Detector.

Parameters

with_query The `WITH` clause allows you to specify one or more subqueries that can be referenced by name in the `UPDATE` query. See WITH Queries (Common Table Expressions) and SELECT for details.

For an `UPDATE` command that includes a `WITH` clause, the clause can only contain `SELECT` commands, the `WITH` clause cannot contain a data-modifying command (`INSERT`, `UPDATE`, or `DELETE`).

It is possible for the query (`SELECT` statement) to also contain a `WITH` clause. In such a case both sets of with_query can be referenced within the `UPDATE` query, but the second one takes precedence since it is more closely nested.

table_name The name (optionally schema-qualified) of the table to update. If `ONLY` is specified before the table name, matching rows are updated in the named table only. If `ONLY` is not specified, matching rows are also updated in any tables inheriting from the named table. Optionally, you can specify `*` after the table name to explicitly indicate that descendant tables are included.

alias A substitute name for the target table. When an alias is provided, it completely hides the actual name of the table. For example, given `UPDATE foo AS f`, the remainder of the `UPDATE` statement must refer to this table as `f` not `foo`.

column_name The name of a column in the table named by table_name. The column name can be qualified with a subfield name or array subscript, if needed. Do not include the table's name in the specification of a target column; for example, `UPDATE table_name SET table_name.col = 1` is invalid.

expression An expression to assign to the column. The expression may use the old values of this and other columns in the table.

DEFAULT Set the column to its default value (which will be NULL if no specific default expression has been assigned to it).

sub-SELECT A `SELECT` sub-query that produces as many output columns as are listed in the parenthesized column list preceding it. The sub-query must yield no more than one row when executed. If it yields one row, its column values are assigned to the target columns; if it yields no rows, NULL values are assigned to the target columns. The sub-query can refer to old values of the current row of the table being updated.

from_item A table expression allowing columns from other tables to appear in the `WHERE` condition and the update expressions. This uses the same syntax as the `FROM` clause of a SELECT statement; for example, you can specify an alias for the table name. Do not repeat the target table as a from_item unless you intend a self-join (in which case it must appear with an alias in the from_item).

condition An expression that returns a value of type `boolean`. Only rows for which this expression returns `true` will be updated.

cursor_name The name of the cursor to use in a `WHERE CURRENT OF` condition. The row to be updated is the one most recently fetched from the cursor. The cursor must be a non-grouping query on the `UPDATE`'s target table. Note that `WHERE CURRENT OF` cannot be specified together with a Boolean condition. See DECLARE for more information about using cursors with `WHERE CURRENT OF`.

The `UPDATE...WHERE CURRENT OF` statement can only be run on the server, for example in an interactive psql session or a script. Language extensions such as PL/pgSQL do not have support for updatable cursors.

output_expression An expression to be computed and returned by the `UPDATE` command after each row is updated. The expression may use any column names of the table named by table_name or table(s) listed in `FROM`. Write `*` to return all columns.

output_name A name to use for a returned column.

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Outputs

On successful completion, an `UPDATE` command returns a command tag of the form:

```
UPDATE <count>
```

The count is the number of rows updated, including matched rows whose values did not change. If count is 0, no rows were updated by the query (this is not considered an error).

If the `UPDATE` command contains a `RETURNING` clause, the result will be similar to that of a `SELECT` statement containing the columns and values defined in the `RETURNING` list, computed over the row(s) updated by the command.

Notes

When a `FROM` clause is present, the target table is joined to the tables mentioned in the from_item list, and each output row of the join represents an update operation for the target table. When using `FROM` , ensure that the join produces at most one output row for each row to be modified. In other words, a target row should not join to more than one row from the other table(s). If it does, then only one of the join rows will be used to update the target row, but which one will be used is not readily predictable.

Because of this indeterminacy, referencing other tables only within sub-selects is safer, though often harder to read and slower than using a join.

For a partitioned table, all of the child tables are locked during the `UPDATE` operation when the Global Deadlock Detector is not enabled (the default). Only some of the leaf child tables are locked when the Global Deadlock Detector is enabled. For information about the Global Deadlock Detector, see Global Deadlock Detector.

In the case of a partitioned table, updating a row might cause it to no longer satisfy the partition constraint of the containing partition. In that case, if there is some other partition in the partition tree for which this row satisfies its partition constraint, then the row is moved to that partition. If there is no such partition, an error will occur. Behind the scenes, the row movement is actually a `DELETE` and `INSERT` operation.

There is a possibility that a concurrent `UPDATE` or `DELETE` on the row being moved will generate a serialization failure error. Suppose session 1 is performing an `UPDATE` on a partition key, and meanwhile a concurrent session 2 for which this row is visible performs an `UPDATE` or `DELETE` operation on this row. In such case, session 2's `UPDATE` or `DELETE` will detect the row movement and raise a serialization failure error (which always returns with an SQLSTATE code '40001'). Applications may wish to retry the transaction if this occurs. In the usual case where the table is not partitioned, or where there is no row movement, session 2 would have identified the newly updated row and carried out the `UPDATE/DELETE` on this new row version.

Note that while rows can be moved from local partitions to a foreign-table partition (provided the foreign data wrapper supports tuple routing), they cannot be moved from a foreign-table partition to another partition.

Examples

Change the word `Drama` to `Dramatic` in the column `kind` of the table `films` :

```
UPDATE films SET kind = 'Dramatic' WHERE kind = 'Drama';
```

Adjust temperature entries and reset precipitation to its default value in one row of the table `weather` :

```
UPDATE weather SET temp_lo = temp_lo+1, temp_hi =
temp_lo+15, prcp = DEFAULT
WHERE city = 'San Francisco' AND date = '2016-07-03';
```

Perform the same operation and return the updated entries:

```
UPDATE weather SET temp_lo = temp_lo+1, temp_hi = temp_lo+15, prcp = DEFAULT
  WHERE city = 'San Francisco' AND date = '2003-07-03'
  RETURNING temp_lo, temp_hi, prcp;
```

Use the alternative column-list syntax to do the same update:

```
UPDATE weather SET (temp_lo, temp_hi, prcp) = (temp_lo+1,
temp_lo+15, DEFAULT)
WHERE city = 'San Francisco' AND date = '2016-07-03';
```

Increment the sales count of the salesperson who manages the account for Acme Corporation, using the `FROM` clause syntax (assuming both tables being joined are distributed in WarehousePG on the `id` column):

```
UPDATE employees SET sales_count = sales_count + 1 FROM
accounts
WHERE accounts.name = 'Acme Corporation'
AND employees.id = accounts.id;
```

Perform the same operation, using a sub-select in the `WHERE` clause:

```
UPDATE employees SET sales_count = sales_count + 1 WHERE id =
  (SELECT id FROM accounts WHERE name = 'Acme Corporation');
```

Update contact names in an `accounts` table to match the currently assigned salesmen:

```
UPDATE accounts SET (contact_first_name, contact_last_name) =
    (SELECT first_name, last_name FROM salesmen
     WHERE salesmen.id = accounts.sales_id);
```

A similar result could be accomplished with a join:

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```
UPDATE accounts SET contact_first_name = first_name,
                    contact_last_name = last_name
  FROM salesmen WHERE salesmen.id = accounts.sales_id;
```

However, the second query may give unexpected results if `salesmen.id` is not a unique key, whereas the first query is guaranteed to raise an error if there are multiple `id` matches. Also, if there is no match for a particular `accounts.sales_id` entry, the first query will set the corresponding name fields to NULL, whereas the second query will not update that row at all.

Update statistics in a `summary` table to match the current data:

```
UPDATE summary s SET (sum_x, sum_y, avg_x, avg_y) =
    (SELECT sum(x), sum(y), avg(x), avg(y) FROM data d
     WHERE d.group_id = s.group_id);
```

Attempt to insert a new stock item along with the quantity of stock. If the item already exists, instead update the stock count of the existing item. To do this without failing the entire transaction, use savepoints.

```
BEGIN;
-- other operations
SAVEPOINT sp1;
INSERT INTO wines VALUES('Chateau Lafite 2003', '24');
-- Assume the above fails because of a unique key violation,
-- so now we issue these commands:
ROLLBACK TO sp1;
UPDATE wines SET stock = stock + 24 WHERE winename = 'Chateau
Lafite 2003';
-- continue with other operations, and eventually
COMMIT;
```

Compatibility

This command conforms to the SQL standard, except that the `FROM` and `RETURNING` clauses are WarehousePG extensions, as is the ability to use `WITH` with `UPDATE`.

Some other database systems offer a `FROM` option in which the target table is supposed to be listed again within `FROM`. That is not how WarehousePG interprets `FROM`. Be careful when porting applications that use this extension.

According to the standard, the source value for a parenthesized sub-list of target column names can be any row-valued expression yielding the correct number of columns. WarehousePG only allows the source value to be a row constructor or a sub-`SELECT`. You can specify an individual column's updated value as `DEFAULT` in the row-constructor case, but not inside a sub-`SELECT`.

See Also

DECLARE, DELETE, SELECT, INSERT

Parent topic: SQL Commands

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7.1.175 VACUUM

Garbage-collects and optionally analyzes a database.

Synopsis

```
VACUUM [ (<option> [, ...]) ] [<table_name> [(<column_name> [, ...] )]]
VACUUM [FULL] [FREEZE] [VERBOSE] [ANALYZE]  [<table_name> [(<column_name> [, ...] )]]
where <option> can be one of:
    FULL [ <boolean> ]
    FREEZE [ <boolean> ]
    VERBOSE [ <boolean> ]
    ANALYZE [ <boolean> ]
    DISABLE_PAGE_SKIPPING [ <boolean> ]
    SKIP_LOCKED [ <boolean> ]
    INDEX_CLEANUP [ <boolean> ]
    TRUNCATE [ <boolean> ]
    SKIP_DATABASE_STATS [ <boolean> ]
    ONLY_DATABASE_STATS [ <boolean> ]
    AO_AUX_ONLY [ <boolean> ]
```

Description

`VACUUM` reclaims storage occupied by deleted tuples. In normal WarehousePG operation, tuples that are deleted or obsoleted by an update are not physically removed from their table; they remain present on disk until a `VACUUM` is done. Therefore it is necessary to perform `VACUUM` periodically, especially on frequently-updated tables.

When no table list is specified, `VACUUM` processes every table in the current database that the current user has permission to vacuum. When a table is specified, `VACUUM` processes only that table.

`VACUUM ANALYZE` performs a `VACUUM` and then an `ANALYZE` for each selected table. This is a handy combination form for routine maintenance scripts. See ANALYZE for more details about its processing.

`VACUUM` (without `FULL`) marks deleted and obsoleted data in tables and indexes for future reuse.

With heap tables, it reclaims for re-use only if the space is at the end of the table and an exclusive table lock can be easily obtained. Unused space at the start or middle of a table remains as is. This form of the command can operate in parallel with normal reading and writing of the table, as an exclusive lock is not obtained. However, extra space is not returned to the operating system (in most cases); it is just kept available for re-use within the same table. `VACUUM FULL` rewrites the entire contents of the table into a new disk file with no extra space, allowing unused space to be returned to the operating system. This form is much slower and requires an `ACCESS EXCLUSIVE` lock on each table while it is being processed.

With append-optimized tables, `VACUUM` compacts a table by first vacuuming the indexes, then compacting each segment file in turn, if applicable, and finally vacuuming auxiliary relations and updating statistics. On each segment, visible rows are copied from the current segment file to a new segment file, and then the current segment file is scheduled to be dropped and the new segment file is made available. Plain `VACUUM` of an append-optimized table allows scans, inserts, deletes, and updates of the table while a segment file is compacted. However, an `EXCLUSIVE` lock is taken briefly to drop the current segment file and activate the new segment file.

`VACUUM FULL` for append-optimized tables does more extensive processing, including moving of tuples across blocks to try to compact the table to the minimum number of disk blocks. However this may also happen for `VACUUM` (without `FULL`) based on how many hidden tuples there are. `VACUUM FULL` requires an `ACCESS EXCLUSIVE` lock on each table while it is being processed. The `ACCESS EXCLUSIVE` lock guarantees that the holder is the only transaction accessing the table in any way.

When the option list is surrounded by parentheses, the options can be written in any order. Without parentheses, options must be specified in exactly the order shown above. The parenthesized syntax was added in WarehousePG 6.0; the unparenthesized syntax is deprecated.

> **Important**
>
> For more important information on the use of `VACUUM`, `VACUUM FULL`, and `VACUUM ANALYZE`, see Notes.

Parameters

FULL

Selects a *full* vacuum, which may reclaim more space, but takes much longer and exclusively locks the table. This method also requires extra disk space, since it writes a new copy of the table and doesn't release the old copy until the operation is complete. Use this only when a significant amount of space needs to be reclaimed from within the table.

FREEZE

Selects aggressive *freezing* of tuples. Specifying `FREEZE` is equivalent to performing `VACUUM` with the vacuum_freeze_min_age and `vacuum_freeze_table_age` server configuration parameter set to zero. Aggressive freezing is always performed when the table is rewritten, so this option is redundant when `FULL` is specified.

VERBOSE

Prints a detailed vacuum activity report for each table.

ANALYZE

Updates statistics used by the planner to determine the most efficient way to run a query.

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DISABLE_PAGE_SKIPPING

Normally, `VACUUM` skips pages based on the visibility map. It always skips pages where all tuples are known to be frozen, and skips those where all tuples are known to be visible to all transactions except when performing an aggressive vacuum. Except when performing an aggressive vacuum, it skips some pages in order to avoid waiting for other sessions to finish using them. This option disables all page-skipping behavior, you may use this option only when the contents of the visibility map are suspect, which should happen only if there is a hardware or software issue causing database corruption.

SKIP_LOCKED

Specifies that `VACUUM` should not wait for any conflicting locks to be released when beginning work on a relation: if it cannot lock a relation immediately without waiting, it skips the relation. Note that even with this option, `VACUUM` may still block when opening the relation's indexes. Additionally, `VACUUM ANALYZE` may still block when acquiring sample rows from partitions, table inheritance children, and some types of foreign tables. Also, while `VACUUM` ordinarily processes all partitions of specified partitioned tables, this option will cause `VACUUM` to skip all partitions if there is a conflicting lock on the partitioned table.

INDEX_CLEANUP

Specifies that `VACUUM` should attempt to remove index entries pointing to dead tuples. This is normally the desired behavior and is the default unless you override it by setting the `vacuum_index_cleanup` server configuration parameter to `false` for the table you run `VACUUM` against. Setting this option to `false` may be useful when you need to make vacuum run as quickly as possible, for example, to avoid imminent transaction ID wraparound. However, if you do not perform index cleanup regularly, performance may suffer, because as the table is modified, indexes accumulate dead tuples and the table itself accumulates dead line pointers that cannot be removed until index cleanup completes. This option has no effect for tables that do not have an index and is ignored if the `FULL` option is specified.

TRUNCATE

Specifies that `VACUUM` should attempt to truncate any empty pages at the end of the table and allow the disk space for the truncated pages to be returned to the operating system. This is normally the desired behavior and is the default unless the `vacuum_truncate` option has been set to false for the table to be vacuumed. Setting this option to `false` may be useful to avoid `ACCESS EXCLUSIVE` lock on the table that the truncation requires. This option is ignored if the `FULL` option is specified.

SKIP_DATABASE_STATS

Specifies that `VACUUM` should skip updating the database-wide statistics about oldest unfrozen XIDs. `VACUUM` normally updates these statistics once at the end of the command. This operation may take a while in a database with a very large number of tables, and accomplishes nothing unless the table that had contained the oldest unfrozen XID was among those vacuumed. If multiple `VACUUM` commands are issued in parallel, only one of them can update the database-wide statistics at a time. Consequently, if an application intends to issue a series of many `VACUUM` commands, it may be helpful to set this option in all but the last such command; or set it in all the commands and separately issue `VACUUM (ONLY_DATABASE_STATS)` afterwards.

ONLY_DATABASE_STATS

Specifies that `VACUUM` do nothing except update the database-wide statistics about oldest unfrozen XIDs. When this option is specified, the `<table_and_columns>` list must be empty, and no other option may be enabled except `VERBOSE`.

AO_AUX_ONLY

Runs `VACUUM` against all auxiliary tables of an append-optimized table. It does not run `VACUUM` against the append-optimized table. If run against a non-append-optimized table with no child partitions, no action takes place. If run against a heap table with an append-optimized partition, `VACUUM` vacuums the auxiliary tables of this partition. You may also use `AO_AUX_ONLY` without specifying a table to run against all append-optimized tables in the database.

`<boolean>`

Specifies whether the selected option should be turned on or off. You can write `TRUE`, `ON`, or `1` to enable the option, and `FALSE`, `OFF`, or `0` to deactivate it. If the boolean value is omitted, `TRUE` is assumed.

`<ao_table>`

The name of a table whose auxiliary tables are to be vacuumed, most often an append-optimized table.

`<table_name>`

The name (optionally schema-qualified) of a specific table or materialized view to vacuum. If the specified table is a partitioned table, all of its leaf partitions are vacuumed. Defaults to all tables in the current database.

`<column_name>`

The name of a specific column to analyze. Defaults to all columns. If a column list is specified, `ANALYZE` must also be specified.

Outputs

When `VERBOSE` is specified, `VACUUM` emits progress messages to indicate which table is currently being processed. Various statistics about the tables are printed as well.

Notes

To vacuum a table, one must ordinarily be the table's owner or a superuser. However, database owners are allowed to vacuum all tables in their databases, except shared catalogs. (The restriction for shared catalogs implies that a true database-wide `VACUUM` can only be performed by a superuser.) `VACUUM` skips over any tables that the calling user does not have permission to vacuum.

`VACUUM` cannot be run inside a transaction block.

For tables with GIN indexes, `VACUUM` (in any form) also completes any pending index insertions, by moving pending index entries to the appropriate places in the main GIN index structure.

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Vacuum active databases frequently (at least nightly), in order to remove expired rows. After adding or deleting a large number of rows, running the `VACUUM ANALYZE` command for the affected table might be useful. This updates the system catalogs with the results of all recent changes, and allows the WarehousePG query optimizer to make better choices in planning queries.

`VACUUM FULL` reclaims all expired row space, however it requires an exclusive lock on each table being processed, is a very expensive operation, and might take a long time to complete on large, distributed WarehousePG tables. Perform `VACUUM FULL` operations during database maintenance periods.

The `FULL` option is not recommended for routine use, but might be useful in special cases. An example is when you have deleted or updated most of the rows in a table and would like the table to physically shrink to occupy less disk space and allow faster table scans. `VACUUM FULL` usuallys shrink the table more than a plain `VACUUM` would.

As an alternative to `VACUUM FULL`, you can re-create the table with a `CREATE TABLE AS` statement and drop the old table.

`VACUUM` causes a substantial increase in I/O traffic, which might cause poor performance for other active sessions. Therefore, it is sometimes advisable to use the cost-based vacuum delay.

WarehousePG includes an *autovacuum* facility that you can use to automate routine vacuum maintenance. Refer to The Autovacuum Daemon PostgreSQL documentation for more information.

`VACUUM` commands skip external and foreign tables.

For append-optimized tables, `VACUUM` and `VACUUM FULL` require enough available disk space to accommodate the new segment file during the `VACUUM` or `VACUUM FULL` process. If the ratio of hidden rows to total rows in a segment file is less than a threshold value (10, by default), the segment file is not compacted. The threshold value can be configured with the `gp_appendonly_compaction_threshold` server configuration parameter. `VACUUM FULL` ignores the threshold and rewrites the segment file regardless of the ratio. `VACUUM` can be deactivated for append-optimized tables using the `gp_appendonly_compaction` server configuration parameter. See Server Configuration Parameters for information about the server configuration parameters.

If a concurrent serializable transaction is detected when an append-optimized table is being vacuumed, the current and subsequent segment files are not compacted. If a segment file has been compacted but a concurrent serializable transaction is detected in the transaction that drops the original segment file, the drop is skipped. This could leave one or two segment files in an "awaiting drop" state after the vacuum has completed.

For more information about concurrency control in WarehousePG, see Routine System Maintenance Tasks in the *WarehousePG Administrator Guide*.

Examples

To clean a single table `onek`, analyze it for the optimizer and print a detailed vacuum activity report:

```
VACUUM (VERBOSE, ANALYZE) onek;
```

Vacuum all tables in the current database:

```
VACUUM;
```

Vacuum a specific table only:

```
VACUUM (VERBOSE, ANALYZE) mytable;
```

Vacuum all tables in the current database and collect statistics for the query optimizer:

```
VACUUM ANALYZE;
```

Compatibility

There is no `VACUUM` statement in the SQL standard.

See Also

ANALYZE

Parent topic: SQL Commands

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7.1.176 VALUES

Computes a set of rows.

Synopsis

```
VALUES ( <expression> [, ...] ) [, ...]
   [ORDER BY <sort_expression> [ ASC | DESC | USING <operator> ] [, ...] ]
   [LIMIT { <count> | ALL } ]
   [OFFSET <start> [ ROW | ROWS ] ]
   [FETCH { FIRST | NEXT } [<count> ] { ROW | ROWS } ONLY ]
```

Description

`VALUES` computes a row value or set of row values specified by value expressions. It is most commonly used to generate a "constant table" within a larger command, but it can be used on its own.

When more than one row is specified, all the rows must have the same number of elements. The data types of the resulting table's columns are determined by combining the explicit or inferred types of the expressions appearing in that column, using the same rules as for `UNION`.

Within larger commands, `VALUES` is syntactically allowed anywhere that `SELECT` is. Because it is treated like a `SELECT` by the grammar, it is possible to use the `ORDER BY`, `LIMIT` (or equivalent `FETCH FIRST`), and `OFFSET` clauses with a `VALUES` command.

Parameters

expression A constant or expression to compute and insert at the indicated place in the resulting table (set of rows). In a `VALUES` list appearing at the top level of an `INSERT`, an expression can be replaced by `DEFAULT` to indicate that the destination column's default value should be inserted. `DEFAULT` cannot be used when `VALUES` appears in other contexts.

sort_expression An expression or integer constant indicating how to sort the result rows. This expression may refer to the columns of the `VALUES` result as `column1`, `column2`, etc. For more details, see "The ORDER BY Clause" in the parameters for SELECT.

operator A sorting operator. For more details, see "The ORDER BY Clause" in the parameters forSELECT.

LIMIT count OFFSET start The maximum number of rows to return. For more details, see "The LIMIT Clause" in the parameters forSELECT.

Notes

`VALUES` lists with very large numbers of rows should be avoided, as you may encounter out-of-memory failures or poor performance. `VALUES` appearing within `INSERT` is a special case (because the desired column types are known from the `INSERT`'s target table, and need not be inferred by scanning the `VALUES` list), so it can handle larger lists than are practical in other contexts.

Examples

A bare `VALUES` command:

```
VALUES (1, 'one'), (2, 'two'), (3, 'three');
```

This will return a table of two columns and three rows. It is effectively equivalent to:

```
SELECT 1 AS column1, 'one' AS column2
UNION ALL
SELECT 2, 'two'
UNION ALL
SELECT 3, 'three';
```

More usually, `VALUES` is used within a larger SQL command. The most common use is in `INSERT`:

```
INSERT INTO films (code, title, did, date_prod, kind)
    VALUES ('T_601', 'Yojimbo', 106, '1961-06-16', 'Drama');
```

In the context of `INSERT`, entries of a `VALUES` list can be `DEFAULT` to indicate that the column default should be used here instead of specifying a value:

```
INSERT INTO films VALUES
    ('UA502', 'Bananas', 105, DEFAULT, 'Comedy', '82
minutes'),
    ('T_601', 'Yojimbo', 106, DEFAULT, 'Drama', DEFAULT);
```

`VALUES` can also be used where a sub-`SELECT` might be written, for example in a `FROM` clause:

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```
SELECT f.* FROM films f, (VALUES('MGM', 'Horror'), ('UA',
'Sci-Fi')) AS t (studio, kind) WHERE f.studio = t.studio AND
f.kind = t.kind;
UPDATE employees SET salary = salary * v.increase FROM
(VALUES(1, 200000, 1.2), (2, 400000, 1.4)) AS v (depno,
target, increase) WHERE employees.depno = v.depno AND
employees.sales >= v.target;
```

Note that an `AS` clause is required when `VALUES` is used in a `FROM` clause, just as is true for `SELECT`. It is not required that the `AS` clause specify names for all the columns, but it is good practice to do so. The default column names for `VALUES` are `column1`, `column2`, etc. in WarehousePG, but these names might be different in other database systems.

When `VALUES` is used in `INSERT`, the values are all automatically coerced to the data type of the corresponding destination column. When it is used in other contexts, it may be necessary to specify the correct data type. If the entries are all quoted literal constants, coercing the first is sufficient to determine the assumed type for all:

```
SELECT * FROM machines WHERE ip_address IN
(VALUES('192.168.0.1'::inet), ('192.168.0.10'),
('192.0.2.43'));
```

> **Note** For simple `IN` tests, it is better to rely on the list-of-scalars form of `IN` than to write a `VALUES` query as shown above. The list of scalars method requires less writing and is often more efficient.

Compatibility

`VALUES` conforms to the SQL standard. `LIMIT` and `OFFSET` are WarehousePG extensions; see also under SELECT.

See Also

INSERT, SELECT

Parent topic: SQL Commands

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7.1.177 ALTER RULE

Changes the definition of a rule.

Synopsis

```
ALTER RULE name ON <table_name> RENAME TO <new_name>
```

Description

`ALTER RULE` changes properties of an existing rule. Currently, the only available action is to change the rule's name.

To use `ALTER RULE`, you must own the table or view that the rule applies to.

Parameters

name The name of an existing rule to alter.

table_name The name (optionally schema-qualified) of the table or view that the rule applies to.

new_name The new name for the rule.

Examples

To rename an existing rule:

```
ALTER RULE notify_all ON emp RENAME TO notify_me;
```

Compatibility

`ALTER RULE` is a WarehousePG extension, as is the entire query rewrite system.

See Also

CREATE RULE, DROP RULE

Parent topic: SQL Commands

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7.1.178 ALTER TRIGGER

Changes the definition of a trigger.

Synopsis

```
ALTER TRIGGER <name> ON <table> RENAME TO <newname>
```

Description

`ALTER TRIGGER` changes properties of an existing trigger. The `RENAME` clause changes the name of the given trigger without otherwise changing the trigger definition. You must own the table on which the trigger acts to be allowed to change its properties.

Parameters

name The name of an existing trigger to alter.

table The name of the table on which this trigger acts.

newname The new name for the trigger.

Notes

The ability to temporarily activate or deactivate a trigger is provided by ALTER TABLE, not by `ALTER TRIGGER`, because `ALTER TRIGGER` has no convenient way to express the option of activating or deactivating all of a table's triggers at once.

Note that WarehousePG has limited support of triggers in this release. See CREATE TRIGGER for more information.

Examples

To rename an existing trigger:

```
ALTER TRIGGER emp_stamp ON emp RENAME TO emp_track_chgs;
```

Compatibility

`ALTER TRIGGER` is a WarehousePG extension of the SQL standard.

See Also

ALTER TABLE, CREATE TRIGGER, DROP TRIGGER

Parent topic: SQL Commands

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7.1.179 CREATE TRIGGER

Defines a new trigger. User-defined triggers are not supported in WarehousePG.

Synopsis

```
CREATE TRIGGER <name> {BEFORE | AFTER} {<event> [OR ...]}
       ON <table> [ FOR [EACH] {ROW | STATEMENT} ]
       EXECUTE PROCEDURE <funcname> ( <arguments> )
```

Description

`CREATE TRIGGER` creates a new trigger. The trigger will be associated with the specified table and will run the specified function when certain events occur. If multiple triggers of the same kind are defined for the same event, they will be fired in alphabetical order by name.

> *Important* Due to the distributed nature of a WarehousePG cluster, the use of triggers on data is very limited in WarehousePG. The function used in the trigger must be `IMMUTABLE`, meaning it cannot use information not directly present in its argument list. The function specified in the trigger also cannot run any SQL or modify distributed database objects in any way. Given that triggers are most often used to alter tables (for example, update these other rows when this row is updated), these limitations offer very little practical use of triggers in WarehousePG. For that reason, WarehousePG does not support the use of user-defined triggers in WarehousePG. Triggers cannot be used on append-optimized tables. Event Triggers, which capture only DDL events, *are* supported in WarehousePG. See the PostgreSQL documentation for Event Triggers for additional information.

SELECT does not modify any rows so you can not create `SELECT` triggers. Rules and views are more appropriate in such cases.

Parameters

name The name to give the new trigger. This must be distinct from the name of any other trigger for the same table.

BEFORE AFTER Determines whether the function is called before or after the event. If the trigger fires before the event, the trigger may skip the operation for the current row, or change the row being inserted (for `INSERT` and `UPDATE` operations only). If the trigger fires after the event, all changes, including the last insertion, update, or deletion, are visible to the trigger.

event Specifies the event that will fire the trigger (`INSERT`, `UPDATE`, or `DELETE`). Multiple events can be specified using OR.

table The name (optionally schema-qualified) of the table the trigger is for.

FOR EACH ROW FOR EACH STATEMENT This specifies whether the trigger procedure should be fired once for every row affected by the trigger event, or just once per SQL statement. If neither is specified, `FOR EACH STATEMENT` is the default. A trigger that is marked `FOR EACH ROW` is called once for every row that the operation modifies. In contrast, a trigger that is marked `FOR EACH STATEMENT` only runs once for any given operation, regardless of how many rows it modifies.

funcname A user-supplied function that is declared as `IMMUTABLE`, taking no arguments, and returning type `trigger`, which is run when the trigger fires. This function must not run SQL or modify the database in any way.

arguments An optional comma-separated list of arguments to be provided to the function when the trigger is run. The arguments are literal string constants. Simple names and numeric constants may be written here, too, but they will all be converted to strings. Please check the description of the implementation language of the trigger function about how the trigger arguments are accessible within the function; it may be different from normal function arguments.

Notes

To create a trigger on a table, the user must have the `TRIGGER` privilege on the table.

Examples

Declare the trigger function and then a trigger:

```
CREATE FUNCTION sendmail() RETURNS trigger AS
'$GPHOME/lib/emailtrig.so' LANGUAGE C IMMUTABLE;

CREATE TRIGGER t_sendmail AFTER INSERT OR UPDATE OR DELETE
ON mytable FOR EACH STATEMENT EXECUTE PROCEDURE sendmail();
```

Compatibility

The `CREATE TRIGGER` statement in WarehousePG implements a subset of the SQL standard. The following functionality is currently missing:

- WarehousePG has strict limitations on the function that is called by a trigger, which makes the use of triggers very limited in WarehousePG. For this reason, triggers are not officially supported in WarehousePG.
- SQL allows triggers to fire on updates to specific columns (e.g., `AFTER UPDATE OF col1, col2`).
- SQL allows you to define aliases for the 'old' and 'new' rows or tables for use in the definition of the triggered action (e.g., `CREATE TRIGGER ... ON tablename REFERENCING OLD ROW AS somename NEW ROW AS othername ...`). Since WarehousePG allows trigger procedures to be written in any number of user-defined languages, access to the data is handled in a language-specific way.
- WarehousePG only allows the execution of a user-defined function for the triggered action. The standard allows the execution of a number of other SQL commands, such as `CREATE TABLE` as the triggered action. This limitation is not hard to work around by creating a user-defined function that runs the desired commands.
- SQL specifies that multiple triggers should be fired in time-of-creation order. WarehousePG uses name order, which was judged to be more convenient.
- SQL specifies that `BEFORE DELETE` triggers on cascaded deletes fire after the cascaded `DELETE` completes. The WarehousePG behavior is for `BEFORE DELETE` to always fire before the delete action, even a cascading one. This is considered more consistent.
- The ability to specify multiple actions for a single trigger using `OR` is a WarehousePG extension of the SQL standard.

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See Also

CREATE FUNCTION, ALTER TRIGGER, DROP TRIGGER, CREATE RULE

Parent topic: SQL Commands

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7.1.180 DROP TRIGGER

Removes a trigger.

Synopsis

```
DROP TRIGGER [IF EXISTS] <name> ON <table> [CASCADE | RESTRICT]
```

Description

`DROP TRIGGER` will remove an existing trigger definition. To run this command, the current user must be the owner of the table for which the trigger is defined.

Parameters

IF EXISTS Do not throw an error if the trigger does not exist. A notice is issued in this case.

name The name of the trigger to remove.

table The name (optionally schema-qualified) of the table for which the trigger is defined.

CASCADE Automatically drop objects that depend on the trigger.

RESTRICT Refuse to drop the trigger if any objects depend on it. This is the default.

Examples

Remove the trigger `sendmail` on table `expenses`;

```
DROP TRIGGER sendmail ON expenses;
```

Compatibility

The `DROP TRIGGER` statement in WarehousePG is not compatible with the SQL standard. In the SQL standard, trigger names are not local to tables, so the command is simply `DROP TRIGGER name`.

See Also

ALTER TRIGGER, CREATE TRIGGER

Parent topic: SQL Commands

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7.2 Data Types

WarehousePG has a rich set of native data types available to users. Users may also define new data types using the `CREATE TYPE` command. This reference shows all of the built-in data types. In addition to the types listed here, there are also some internally used data types, such as *oid* (object identifier), but those are not documented in this guide.

Additional modules that you register may also install new data types. The `hstore` module, for example, introduces a new data type and associated functions for working with key-value pairs. See hstore. The `citext` module adds a case-insensitive text data type. See citext.

The following data types are specified by SQL: *bit*, *bit varying*, *boolean*, *character varying*, *varchar*, *character*, *char*, *date*, *double precision*, *integer*, *interval*, *numeric*, *decimal*, *real*, *smallint*, *time* (with or without time zone), and *timestamp* (with or without time zone).

Each data type has an external representation determined by its input and output functions. Many of the built-in types have obvious external formats. However, several types are either unique to PostgreSQL (and WarehousePG), such as geometric paths, or have several possibilities for formats, such as the date and time types. Some of the input and output functions are not invertible. That is, the result of an output function may lose accuracy when compared to the original input.

Name	Alias	Size	Range	Description
bigint	int8	8 bytes	-9223372036854775808 to 9223372036854775807	large range integer
bigserial	serial8	8 bytes	1 to 9223372036854775807	large autoincrementing integer
bit [(n)]		*n* bits	bit string constant	fixed-length bit string
bit varying [(n)][1]	varbit	actual number of bits	bit string constant	variable-length bit string
boolean	bool	1 byte	true/false, t/f, yes/no, y/n, 1/0	logical boolean (true/false)
box		32 bytes	((x1,y1),(x2,y2))	rectangular box in the plane - not allowed in distribution key columns.
bytea[1]		1 byte + *binary string*	sequence of octets	variable-length binary string
character [(n)][1]	char [(n)]	1 byte + *n*	strings up to *n* characters in length	fixed-length, blank padded
character varying [(n)][1]	varchar [(n)]	1 byte + *string size*	strings up to *n* characters in length	variable-length with limit
cidr		12 or 24 bytes		IPv4 and IPv6 networks
circle		24 bytes	<(x,y),r> (center and radius)	circle in the plane - not allowed in distribution key columns.
date		4 bytes	4713 BC - 294,277 AD	calendar date (year, month, day)
decimal [(p, s)][1]	numeric [(p, s)]	variable	no limit	user-specified precision, exact
double precision	float8 float	8 bytes	15 decimal digits precision	variable-precision, inexact
inet		12 or 24 bytes		IPv4 and IPv6 hosts and networks
integer	int, int4	4 bytes	-2147483648 to +2147483647	usual choice for integer
interval [fields] [(p)]		16 bytes	-178000000 years to 178000000 years	time span
json		1 byte + json size	json of any length	variable unlimited length
jsonb		1 byte + binary string	json of any length in a decomposed binary format	variable unlimited length
lseg		32 bytes	((x1,y1),(x2,y2))	line segment in the plane - not allowed in distribution key columns.
macaddr		6 bytes		MAC addresses
macaddr8		8 bytes		MAC addresses (EUI-64 format)
money		8 bytes	-92233720368547758.08 to +92233720368547758.07	currency amount
path[1]		16+16n bytes	[(x1,y1),...]	geometric path in the plane - not allowed in distribution key columns.
point		16 bytes	(x,y)	geometric point in the plane - not allowed in distribution key columns.
polygon		40+16n bytes	((x1,y1),...)	closed geometric path in the plane - not allowed in distribution key columns.
real	float4	4 bytes	6 decimal digits precision	variable-precision, inexact
serial	serial4	4 bytes	1 to 2147483647	autoincrementing integer
smallint	int2	2 bytes	-32768 to +32767	small range integer
text[1]		1 byte + *string size*	strings of any length	variable unlimited length
time [(p)] [without time zone]		8 bytes	00:00:00[.000000] - 24:00:00[.000000]	time of day only
time [(p)] with time zone	timetz	12 bytes	00:00:00+1359 - 24:00:00-1359	time of day only, with time zone
timestamp [(p)] [without time zone]		8 bytes	4713 BC - 294,277 AD	both date and time
timestamp [(p)] with time zone	timestamptz	8 bytes	4713 BC - 294,277 AD	both date and time, with time zone
uuid		16 bytes		Universally Unique Identifiers according to RFC 4122, ISO/IEC 9834-8:2005
xml[1]		1 byte + *xml size*	xml of any length	variable unlimited length
txid_snapshot				user-level transaction ID snapshot

- Date/Time Types
- Pseudo-Types
- Text Search Data Types
- Range Types

Parent topic: WarehousePG Reference Guide

[1] For variable length data types, if the data is greater than or equal to 127 bytes, the storage overhead is 4 bytes instead of 1.

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7.2.1 Date/Time Types

WarehousePG supports the full set of SQL date and time types, shown in Table 1. The operations available on these data types are described in Date/Time Functions and Operators in the PostgreSQL documentation. Dates are counted according to the Gregorian calendar, even in years before that calendar was introduced (see History of Units in the PostgreSQL documentation for more information).

Name	Storage Size	Description	Low Value	High Value	Resolution
timestamp [(p)] [without time zone]	8 bytes	both date and time (no time zone)	4713 BC	294276 AD	1 microsecond / 14 digits
timestamp [(p)] with time zone	8 bytes	both date and time, with time zone	4713 BC	294276 AD	1 microsecond / 14 digits
date	4 bytes	date (no time of day)	4713 BC	5874897 AD	1 day
time [(p)] [without time zone]	8 bytes	time of day (no date)	00:00:00	24:00:00	1 microsecond / 14 digits
time [(p)] with time zone	12 bytes	times of day only, with time zone	00:00:00+1459	24:00:00-1459	1 microsecond / 14 digits
interval [fields] [(p)]	16 bytes	time interval	-178000000 years	178000000 years	1 microsecond / 14 digits

> **Note** The SQL standard requires that writing just `timestamp` be equivalent to `timestamp without time zone`, and WarehousePG honors that behavior. `timestamptz` is accepted as an abbreviation for `timestamp with time zone`; this is a PostgreSQL extension.

`time`, `timestamp`, and `interval` accept an optional precision value p which specifies the number of fractional digits retained in the seconds field. By default, there is no explicit bound on precision. The allowed range of p is from 0 to 6 for the `timestamp` and `interval` types.

> **Note** When `timestamp` values are stored as eight-byte integers (currently the default), microsecond precision is available over the full range of values. When `timestamp` values are stored as double precision floating-point numbers instead (a deprecated compile-time option), the effective limit of precision might be less than 6. `timestamp` values are stored as seconds before or after midnight 2000-01-01. When `timestamp` values are implemented using floating-point numbers, microsecond precision is achieved for dates within a few years of 2000-01-01, but the precision degrades for dates further away. Note that using floating-point datetimes allows a larger range of `timestamp` values to be represented than shown above: from 4713 BC up to 5874897 AD.

The same compile-time option also determines whether `time` and `interval` values are stored as floating-point numbers or eight-byte integers. In the floating-point case, large `interval` values degrade in precision as the size of the interval increases.

For the `time` types, the allowed range of p is from 0 to 6 when eight-byte integer storage is used, or from 0 to 10 when floating-point storage is used.

The `interval` type has an additional option, which is to restrict the set of stored fields by writing one of these phrases:

```
YEAR
MONTH
DAY
HOUR
MINUTE
SECOND
YEAR TO MONTH
DAY TO HOUR
DAY TO MINUTE
DAY TO SECOND
HOUR TO MINUTE
HOUR TO SECOND
MINUTE TO SECOND
```

Note that if both fields and p are specified, the fields must include `SECOND`, since the precision applies only to the seconds.

The type `time with time zone` is defined by the SQL standard, but the definition exhibits properties which lead to questionable usefulness. In most cases, a combination of `date`, `time`, `timestamp without time zone`, and `timestamp with time zone` should provide a complete range of date/time functionality required by any application.

The types `abstime` and `reltime` are lower precision types which are used internally. You are discouraged from using these types in applications; these internal types might disappear in a future release.

WarehousePG 6 and later releases do not automatically cast text from the deprecated timestamp format `YYYYMMDDHH24MISS`. The format could not be parsed unambiguously in previous WarehousePG releases.

For example, this command returns an error in WarehousePG 6. In previous releases, a timestamp is returned.

```
# select to_timestamp('20190905140000');
```

In WarehousePG 6, this command returns a timestamp.

```
# select to_timestamp('20190905140000','YYYYMMDDHH24MISS');
```

Date/Time Input

Date and time input is accepted in almost any reasonable format, including ISO 8601, SQL-compatible, traditional POSTGRES, and others. For some formats, ordering of day, month, and year in date input is ambiguous and there is support for specifying the expected ordering of these fields. Set the DateStyle parameter to `MDY` to select month-day-year interpretation, `DMY` to select day-month-year interpretation, or `YMD` to select year-month-day interpretation.

WarehousePG is more flexible in handling date/time input than the SQL standard requires. See Appendix B. Date/Time Support in the PostgreSQL documentation for the exact parsing rules of date/time input and for the recognized text fields including months, days of the week, and time zones.

Remember that any date or time literal input needs to be enclosed in single quotes, like text strings. SQL requires the following syntax

```
<type> [ (<p>) ] '<value>'
```

where p is an optional precision specification giving the number of fractional digits in the seconds field. Precision can be specified for `time`, `timestamp`, and `interval` types. The allowed values are mentioned above. If no precision is specified in a constant specification, it defaults to the precision of the literal value.

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Dates

Table 2 shows some possible inputs for the `date` type.

Example	Description
1999-01-08	ISO 8601; January 8 in any mode (recommended format)
January 8, 1999	unambiguous in any datestyle input mode
1/8/1999	January 8 in `MDY` mode; August 1 in `DMY` mode
1/18/1999	January 18 in `MDY` mode; rejected in other modes
01/02/03	January 2, 2003 in `MDY` mode; February 1, 2003 in `DMY` mode; February 3, 2001 in `YMD` mode
1999-Jan-08	January 8 in any mode
Jan-08-1999	January 8 in any mode
08-Jan-1999	January 8 in any mode
99-Jan-08	January 8 in `YMD` mode, else error
08-Jan-99	January 8, except error in `YMD` mode
Jan-08-99	January 8, except error in `YMD` mode
19990108	ISO 8601; January 8, 1999 in any mode
990108	ISO 8601; January 8, 1999 in any mode
1999.008	year and day of year
J2451187	Julian date
January 8, 99 BC	year 99 BC

Times

The time-of-day types are `time [ (p) ] without time zone` and `time [ (p) ] with time zone`. `time` alone is equivalent to `time without time zone`.

Valid input for these types consists of a time of day followed by an optional time zone. (See Time Input and Time Zone Input.) If a time zone is specified in the input for `time without time zone`, it is silently ignored. You can also specify a date but it will be ignored, except when you use a time zone name that involves a daylight-savings rule, such as `America/New_York`. In this case specifying the date is required in order to determine whether standard or daylight-savings time applies. The appropriate time zone offset is recorded in the `time with time zone` value.

Time Input

Example	Description
`04:05:06.789`	ISO 8601
`04:05:06`	ISO 8601
`04:05`	ISO 8601
`040506`	ISO 8601
`04:05 AM`	same as 04:05; AM does not affect value
`04:05 PM`	same as 16:05; input hour must be <= 12
`04:05:06.789-8`	ISO 8601
`04:05:06-08:00`	ISO 8601
`04:05-08:00`	ISO 8601
`040506-08`	ISO 8601
`04:05:06 PST`	time zone specified by abbreviation
`2003-04-12 04:05:06 America/New_York`	time zone specified by full name

Time Zone Input

Example	Description
`PST`	Abbreviation (for Pacific Standard Time)
`America/New_York`	Full time zone name
`PST8PDT`	POSIX-style time zone specification
`-8:00`	ISO-8601 offset for PST
`-800`	ISO-8601 offset for PST
`-8`	ISO-8601 offset for PST
`zulu`	Military abbreviation for UTC
`z`	Short form of `zulu`

Refer to Time Zones for more information on how to specify time zones.

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Time Stamps

Valid input for the time stamp types consists of the concatenation of a date and a time, followed by an optional time zone, followed by an optional `AD` or `BC`. (Alternatively, `AD`/`BC` can appear before the time zone, but this is not the preferred ordering.) Thus: `1999-01-08 04:05:06` and: `1999-01-08 04:05:06 -8:00` are valid values, which follow the ISO 8601 standard. In addition, the common format: `January 8 04:05:06 1999 PST` is supported.

The SQL standard differentiates `timestamp without time zone` and `timestamp with time zone` literals by the presence of a `+` or `-` symbol and time zone offset after the time. Hence, according to the standard, `TIMESTAMP '2004-10-19 10:23:54'` is a `timestamp without time zone`, while `TIMESTAMP '2004-10-19 10:23:54+02'` is a `timestamp with time zone`. WarehousePG never examines the content of a literal string before determining its type, and therefore will treat both of the above as `timestamp without time zone`. To ensure that a literal is treated as `timestamp with time zone`, give it the correct explicit type: `TIMESTAMP WITH TIME ZONE '2004-10-19 10:23:54+02'` In a literal that has been determined to be `timestamp without time zone`, WarehousePG will silently ignore any time zone indication. That is, the resulting value is derived from the date/time fields in the input value, and is not adjusted for time zone.

For `timestamp with time zone`, the internally stored value is always in UTC (Universal Coordinated Time, traditionally known as Greenwich Mean Time, GMT). An input value that has an explicit time zone specified is converted to UTC using the appropriate offset for that time zone. If no time zone is stated in the input string, then it is assumed to be in the time zone indicated by the system's `TimeZone` parameter, and is converted to UTC using the offset for the timezone zone.

When a `timestamp with time zone` value is output, it is always converted from UTC to the current timezone zone, and displayed as local time in that zone. To see the time in another time zone, either change timezone or use the `AT TIME ZONE` construct (see AT TIME ZONE in the PostgreSQL documentation).

Conversions between `timestamp without time zone` and `timestamp with time zone` normally assume that the `timestamp without time zone` value should be taken or given as timezone local time. A different time zone can be specified for the conversion using `AT TIME ZONE`.

Special Values

WarehousePG supports several special date/time input values for convenience, as shown in Special Date/Time Inputs. The values `infinity` and `-infinity` are specially represented inside the system and will be displayed unchanged; but the others are simply notational shorthands that will be converted to ordinary date/time values when read. (In particular, `now` and related strings are converted to a specific time value as soon as they are read.) All of these values need to be enclosed in single quotes when used as constants in SQL commands.

Special Date/Time Inputs

Input String	Valid Types	Description
`epoch`	`date`, `timestamp`	1970-01-01 00:00:00+00 (Unix system time zero)
`infinity`	`date`, `timestamp`	later than all other time stamps
`-infinity`	`date`, `timestamp`	earlier than all other time stamps
`now`	`date`, `time`, `timestamp`	current transaction's start time
`today`	`date`, `timestamp`	midnight today
`tomorrow`	`date`, `timestamp`	midnight tomorrow
`yesterday`	`date`, `timestamp`	midnight yesterday
`allballs`	`time`	00:00:00.00 UTC

The following SQL-compatible functions can also be used to obtain the current time value for the corresponding data type: `CURRENT_DATE`, `CURRENT_TIME`, `CURRENT_TIMESTAMP`, `LOCALTIME`, `LOCALTIMESTAMP`. The latter four accept an optional subsecond precision specification. (See Current Date/Time in the PostgreSQL documentation.) Note that these are SQL functions and are *not* recognized in data input strings.

Date/Time Output

The output format of the date/time types can be set to one of the four styles ISO 8601, SQL (Ingres), traditional POSTGRES (Unix `date` format), or German. The default is the ISO format. (The SQL standard requires the use of the ISO 8601 format. The name of the `SQL` output format is a historical accident.) Date/Time Output Styles shows examples of each output style. The output of the `date` and `time` types is generally only the date or time part in accordance with the given examples. However, the POSTGRES style outputs date-only values in ISO format.

Date/Time Output Styles

Style Specification	Description	Example
`ISO`	ISO 8601, SQL standard	`1997-12-17 07:37:16-08`
`SQL`	traditional style	`12/17/1997 07:37:16.00 PST`
`Postgres`	original style	`Wed Dec 17 07:37:16 1997 PST`
`German`	regional style	`17.12.1997 07:37:16.00 PST`

> **Note** ISO 8601 specifies the use of uppercase letter `T` to separate the date and time. WarehousePG accepts that format on input, but on output it uses a space rather than `T`, as shown above. This is for readability and for consistency with RFC 3339 as well as some other database systems.

In the SQL and POSTGRES styles, day appears before month if DMY field ordering has been specified, otherwise month appears before day. (See Date Input for how this setting also affects interpretation of input values.) Date Order Conventions shows examples.

Date Order Conventions

datestyle Setting	Input Ordering	Example Output
`SQL, DMY`	day/month/year	`17/12/1997 15:37:16.00 CET`
`SQL, MDY`	month/day/year	`12/17/1997 07:37:16.00 PST`
`Postgres, DMY`	day/month/year	`Wed 17 Dec 07:37:16 1997 PST`

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The date/time style can be selected by the user using the `SET datestyle` command, the `DateStyle` parameter in the `postgresql.conf` configuration file, or the `PGDATESTYLE` environment variable on the server or client.

The formatting function `to_char` (see Data Type Formatting Functions) is also available as a more flexible way to format date/time output.

Time Zones

Time zones, and time-zone conventions, are influenced by political decisions, not just earth geometry. Time zones around the world became somewhat standardized during the 1900s, but continue to be prone to arbitrary changes, particularly with respect to daylight-savings rules. WarehousePG uses the widely-used IANA (Olson) time zone database for information about historical time zone rules. For times in the future, the assumption is that the latest known rules for a given time zone will continue to be observed indefinitely far into the future.

WarehousePG endeavors to be compatible with the SQL standard definitions for typical usage. However, the SQL standard has an odd mix of date and time types and capabilities. Two obvious problems are:

1. Although the `date` type cannot have an associated time zone, the `time` type can. Time zones in the real world have little meaning unless associated with a date as well as a time, since the offset can vary through the year with daylight-saving time boundaries.
2. The default time zone is specified as a constant numeric offset from UTC. It is therefore impossible to adapt to daylight-saving time when doing date/time arithmetic across DST boundaries.

To address these difficulties, we recommend using date/time types that contain both date and time when using time zones. We do *not* recommend using the type `time with time zone` (though it is supported by WarehousePG for legacy applications and for compliance with the SQL standard). WarehousePG assumes your local time zone for any type containing only date or time.

All timezone-aware dates and times are stored internally in UTC. They are converted to local time in the zone specified by the `TimeZone` configuration parameter before being displayed to the client.

WarehousePG allows you to specify time zones in three different forms:

1. A full time zone name, for example `America/New_York`. The recognized time zone names are listed in the `pg_timezone_names` view. WarehousePG uses the widely-used IANA time zone data for this purpose, so the same time zone names are also recognized by other software.
2. A time zone abbreviation, for example `PST`. Such a specification merely defines a particular offset from UTC, in contrast to full time zone names which can imply a set of daylight savings transition-date rules as well. The recognized abbreviations are listed in the `pg_timezone_abbrevs` view. You cannot set the configuration parameters TimeZone or log_timezone to a time zone abbreviation, but you can use abbreviations in date/time input values and with the `AT TIME ZONE` operator.
3. In addition to the timezone names and abbreviations, WarehousePG will accept POSIX-style time zone specifications of the form STDoffset or STDoffsetDST, where STD is a zone abbreviation, offset is a numeric offset in hours west from UTC, and DST is an optional daylight-savings zone abbreviation, assumed to stand for one hour ahead of the given offset. For example, if `EST5EDT` were not already a recognized zone name, it would be accepted and would be functionally equivalent to United States East Coast time. In this syntax, a zone abbreviation can be a string of letters, or an arbitrary string surrounded by angle brackets (`<>`). When a daylight-savings zone abbreviation is present, it is assumed to be used according to the same daylight-savings transition rules used in the IANA time zone database's entry. In a standard WarehousePG installation, is the same as `US/Eastern`, so that POSIX-style time zone specifications follow USA daylight-savings rules. If needed, you can adjust this behavior by replacing the file.

In short, this is the difference between abbreviations and full names: abbreviations represent a specific offset from UTC, whereas many of the full names imply a local daylight-savings time rule, and so have two possible UTC offsets. As an example, `2014-06-04 12:00 America/New_York` represents noon local time in New York, which for this particular date was Eastern Daylight Time (UTC-4). So `2014-06-04 12:00 EDT` specifies that same time instant. But `2014-06-04 12:00 EST` specifies noon Eastern Standard Time (UTC-5), regardless of whether daylight savings was nominally in effect on that date.

To complicate matters, some jurisdictions have used the same timezone abbreviation to mean different UTC offsets at different times; for example, in Moscow `MSK` has meant UTC+3 in some years and UTC+4 in others. WarehousePG interprets such abbreviations according to whatever they meant (or had most recently meant) on the specified date; but, as with the `EST` example above, this is not necessarily the same as local civil time on that date.

One should be wary that the POSIX-style time zone feature can lead to silently accepting bogus input, since there is no check on the reasonableness of the zone abbreviations. For example, `SET TIMEZONE TO FOOBAR0` will work, leaving the system effectively using a rather peculiar abbreviation for UTC. Another issue to keep in mind is that in POSIX time zone names, positive offsets are used for locations of Greenwich. Everywhere else, WarehousePG follows the ISO-8601 convention that positive timezone offsets are of Greenwich.

In all cases, timezone names and abbreviations are recognized case-insensitively.

Neither timezone names nor abbreviations are hard-wired into the server; they are obtained from configuration files (see Configuring Localization Settings).

The `TimeZone` configuration parameter can be set in the file , or in any of the other standard ways for setting configuration parameters. There are also some special ways to set it:

1. The SQL command `SET TIME ZONE` sets the time zone for the session. This is an alternative spelling of `SET TIMEZONE TO` with a more SQL-spec-compatible syntax.
2. The `PGTZ` environment variable is used by `libpq` clients to send a `SET TIME ZONE` command to the server upon connection.

Interval Input

`interval` values can be written using the following verbose syntax:

```
<@> <quantity> <unit> <quantity> <unit>... <direction>
```

where quantity is a number (possibly signed); unit is `microsecond`, `millisecond`, `second`, `minute`, `hour`, `day`, `week`, `month`, `year`, `decade`, `century`, `millennium`, or abbreviations or plurals of these units; direction can be `ago` or empty. The at sign (`@`) is optional noise. The amounts of the different units are implicitly added with appropriate sign accounting. `ago` negates all the fields. This syntax is also used for interval output, if IntervalStyle is set to `postgres_verbose`.

Quantities of days, hours, minutes, and seconds can be specified without explicit unit markings. For example, `'1 12:59:10'` is read the same as `'1 day 12 hours 59 min 10 sec'`. Also, a combination of years and months can be specified with a dash; for example `'200-10'` is read the same as `'200 years 10 months'`. (These shorter forms are in fact the only ones allowed by the SQL standard, and are used for output when IntervalStyle is set to `sql_standard`.)

Interval values can also be written as ISO 8601 time intervals, using either the `format with designators` of the standard's section 4.4.3.2 or the `alternative format` of section 4.4.3.3. The format with designators looks like this:

```
P <quantity> <unit> <quantity> <unit> ...  T  <quantity> <unit> ...
```

The string must start with a `P`, and may include a `T` that introduces the time-of-day units. The available unit abbreviations are given in ISO 8601 Interval Unit Abbreviations. Units may be omitted, and may be specified in any order, but units smaller than a day must appear after `T`. In particular, the meaning of `M` depends on whether it is before or after `T`.

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ISO 8601 Interval Unit Abbreviations

Abbreviation	Meaning
Y	Years
M	Months (in the date part)
W	Weeks
D	Days
H	Hours
M	Minutes (in the time part)
S	Seconds

In the alternative format:

```
P  <years>-<months>-<days>   T <hours>:<minutes>:<seconds>
```

the string must begin with `P`, and a `T` separates the date and time parts of the interval. The values are given as numbers similar to ISO 8601 dates.

When writing an interval constant with a fields specification, or when assigning a string to an interval column that was defined with a fields specification, the interpretation of unmarked quantities depends on the fields. For example `INTERVAL '1' YEAR` is read as 1 year, whereas `INTERVAL '1'` means 1 second. Also, field values `to the right` of the least significant field allowed by the fields specification are silently discarded. For example, writing `INTERVAL '1 day 2:03:04' HOUR TO MINUTE` results in dropping the seconds field, but not the day field.

According to the SQL standard all fields of an interval value must have the same sign, so a leading negative sign applies to all fields; for example the negative sign in the interval literal `'-1 2:03:04'` applies to both the days and hour/minute/second parts. WarehousePG allows the fields to have different signs, and traditionally treats each field in the textual representation as independently signed, so that the hour/minute/second part is considered positive in this example. If IntervalStyle is set to `sql_standard` then a leading sign is considered to apply to all fields (but only if no additional signs appear). Otherwise the traditional WarehousePG interpretation is used. To avoid ambiguity, it's recommended to attach an explicit sign to each field if any field is negative.

In the verbose input format, and in some fields of the more compact input formats, field values can have fractional parts; for example `'1.5 week'` or `'01:02:03.45'`. Such input is converted to the appropriate number of months, days, and seconds for storage. When this would result in a fractional number of months or days, the fraction is added to the lower-order fields using the conversion factors 1 month = 30 days and 1 day = 24 hours. For example, `'1.5 month'` becomes 1 month and 15 days. Only seconds will ever be shown as fractional on output.

This table shows some examples of valid `interval` input.

Example	Description
1-2	SQL standard format: 1 year 2 months
3 4:05:06	SQL standard format: 3 days 4 hours 5 minutes 6 seconds
1 year 2 months 3 days 4 hours 5 minutes 6 seconds	Traditional Postgres format: 1 year 2 months 3 days 4 hours 5 minutes 6 seconds
P1Y2M3DT4H5M6S	ISO 8601 `format with designators`: same meaning as above
P0001-02-03T04:05:06	ISO 8601 `alternative format`: same meaning as above

Internally `interval` values are stored as months, days, and seconds. This is done because the number of days in a month varies, and a day can have 23 or 25 hours if a daylight savings time adjustment is involved. The months and days fields are integers while the seconds field can store fractions. Because intervals are usually created from constant strings or `timestamp` subtraction, this storage method works well in most cases, but can cause unexpected results: `SELECT EXTRACT(hours from '80 minutes'::interval); date_part ----------- 1 SELECT EXTRACT(days from '80 hours'::interval); date_part ----------- 0` Functions `justify_days` and `justify_hours` are available for adjusting days and hours that overflow their normal ranges.

Interval Output

The output format of the interval type can be set to one of the four styles `sql_standard`, `postgres`, `postgres_verbose`, or `iso_8601`, using the command `SET intervalstyle`. The default is the `postgres` format. Interval Output Style Examples shows examples of each output style.

The `sql_standard` style produces output that conforms to the SQL standard's specification for interval literal strings, if the interval value meets the standard's restrictions (either year-month only or day-time only, with no mixing of positive and negative components). Otherwise the output looks like a standard year-month literal string followed by a day-time literal string, with explicit signs added to disambiguate mixed-sign intervals.

The output of the `postgres` style matches the output of PostgreSQL releases prior to 8.4 when the DateStyle parameter was set to `ISO`.

The output of the `postgres_verbose` style matches the output of PostgreSQL releases prior to 8.4 when the DateStyle parameter was set to non-`ISO` output.

The output of the `iso_8601` style matches the `format with designators` described in section 4.4.3.2 of the ISO 8601 standard.

Interval Output Style Examples

Style Specification	Year-Month Interval	Day-Time Interval	Mixed Interval
`sql_standard`	1-2	3 4:05:06	-1-2 +3 -4:05:06
`postgres`	1 year 2 mons	3 days 04:05:06	-1 year -2 mons +3 days -04:05:06
`postgres_verbose`	@ 1 year 2 mons	@ 3 days 4 hours 5 mins 6 secs	@ 1 year 2 mons -3 days 4 hours 5 mins 6 secs ago
`iso_8601`	P1Y2M	P3DT4H5M6S	P-1Y-2M3DT-4H-5M-6S

Parent topic: Data Types

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7.2.2 Pseudo-Types

WarehousePG supports special-purpose data type entries that are collectively called *pseudo-types*. A pseudo-type cannot be used as a column data type, but it can be used to declare a function's argument or result type. Each of the available pseudo-types is useful in situations where a function's behavior does not correspond to simply taking or returning a value of a specific SQL data type.

Functions coded in procedural languages can use pseudo-types only as allowed by their implementation languages. The procedural languages all forbid use of a pseudo-type as an argument type, and allow only*void* and *record* as a result type.

A function with the pseudo-type *record* as a return data type returns an unspecified row type. The *record* represents an array of possibly-anonymous composite types. Since composite datums carry their own type identification, no extra knowledge is needed at the array level.

The pseudo-type *void* indicates that a function returns no value.

> **Note** WarehousePG does not support triggers and the pseudo-type *trigger*.

The types *anyelement*, *anyarray*, *anynonarray*, and *anyenum* are pseudo-types called polymorphic types. Some procedural languages also support polymorphic functions using the types*anyarray*, *anyelement*, *anyenum*, and *anynonarray*.

The pseudo-type *anytable* is a WarehousePG type that specifies a table expression—an expression that computes a table. WarehousePG allows this type only as an argument to a user-defined function. SeeTable Value Expressions for more about the *anytable* pseudo-type.

For more information about pseudo-types, see the PostgreSQL documentation aboutPseudo-Types.

Parent topic: Data Types

Polymorphic Types

Four pseudo-types of special interest are *anyelement*, *anyarray*, *anynonarray*, and *anyenum*, which are collectively called *polymorphic* types. Any function declared using these types is said to be a polymorphic function. A polymorphic function can operate on many different data types, with the specific data types being determined by the data types actually passed to it at runtime.

Polymorphic arguments and results are tied to each other and are resolved to a specific data type when a query calling a polymorphic function is parsed. Each position (either argument or return value) declared as*anyelement* is allowed to have any specific actual data type, but in any given call they must all be the same actual type. Each position declared as *anyarray* can have any array data type, but similarly they must all be the same type. If there are positions declared *anyarray* and others declared *anyelement*, the actual array type in the *anyarray* positions must be an array whose elements are the same type appearing in the *anyelement* positions. *anynonarray* is treated exactly the same as *anyelement*, but adds the additional constraint that the actual type must not be an array type. *anyenum* is treated exactly the same as *anyelement*, but adds the additional constraint that the actual type must be an `enum` type.

When more than one argument position is declared with a polymorphic type, the net effect is that only certain combinations of actual argument types are allowed. For example, a function declared as `equal(*anyelement*, *anyelement*)` takes any two input values, so long as they are of the same data type.

When the return value of a function is declared as a polymorphic type, there must be at least one argument position that is also polymorphic, and the actual data type supplied as the arqument determines the actual result type for that call. For example, if there were not already an array subscripting mechanism, one could define a function that implements subscripting as `subscript(*anyarray*, integer) returns *anyelement*` . This declaration constrains the actual first argument to be an array type, and allows the parser to infer the correct result type from the actual first argument's type. Another example is that a function declared as `myfunc(*anyarray*) returns *anyenum*` will only accept arrays of `enum` types.

Note that *anynonarray* and *anyenum* do not represent separate type variables; they are the same type as *anyelement*, just with an additional constraint. For example, declaring a function as `myfunc(*anyelement*, *anyenum*)` is equivalent to declaring it as `myfunc(*anyenum*, *anyenum*)` : both actual arguments must be the same `enum` type.

A variadic function (one taking a variable number of arguments) is polymorphic when its last parameter is declared as `VARIADIC *anyarray*` . For purposes of argument matching and determining the actual result type, such a function behaves the same as if you had declared the appropriate number of *anynonarray* parameters.

For more information about polymorphic types, see the PostgreSQL documentation aboutPolymorphic Arguments and Return Types.

Table Value Expressions

The *anytable* pseudo-type declares a function argument that is a table value expression. The notation for a table value expression is a `SELECT` statement enclosed in a `TABLE()` function. You can specify a distribution policy for the table by adding `SCATTER RANDOMLY` , or a `SCATTER BY` clause with a column list to specify the distribution key.

The `SELECT` statement is run when the function is called and the result rows are distributed to segments so that each segment runs the function with a subset of the result table.

For example, this table expression selects three columns from a table named `customer` and sets the distribution key to the first column:

```
TABLE(SELECT cust_key, name, address FROM customer SCATTER BY 1)
```

The `SELECT` statement may include joins on multiple base tables, `WHERE` clauses, aggregates, and any other valid query syntax.

The *anytable* type is only permitted in functions implemented in the C or C++ languages. The body of the function can access the table using the WarehousePG Server Programming Interface (SPI) or the WarehousePG Partner Connector (GPPC) API.

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7.2.3 Text Search Data Types

WarehousePG provides two data types that are designed to support full text search, which is the activity of searching through a collection of natural-language *documents* to locate those that best match a *query*. The `tsvector` type represents a document in a form optimized for text search; the `tsquery` type similarly represents a text query. Using Full Text Search provides a detailed explanation of this facility, and Text Search Functions and Operators summarizes the related functions and operators.

The `tsvector` and `tsquery` types cannot be part of the distribution key of a WarehousePG table.

Parent topic: Data Types

tsvector

A `tsvector` value is a sorted list of distinct *lexemes*, which are words that have been *normalized* to merge different variants of the same word (see Using Full Text Search for details). Sorting and duplicate-elimination are done automatically during input, as shown in this example:

```
SELECT 'a fat cat sat on a mat and ate a fat rat'::tsvector;
                    tsvector
-----------------------------------------------------
 'a' 'and' 'ate' 'cat' 'fat' 'mat' 'on' 'rat' 'sat'
```

To represent lexemes containing whitespace or punctuation, surround them with quotes:

```
SELECT $$the lexeme '    ' contains spaces$$::tsvector;
                tsvector
-------------------------------------------
 '    ' 'contains' 'lexeme' 'spaces' 'the'
```

(We use dollar-quoted string literals in this example and the next one to avoid the confusion of having to double quote marks within the literals.) Embedded quotes and backslashes must be doubled:

```
SELECT $$the lexeme 'Joe''s' contains a quote$$::tsvector;
                   tsvector
------------------------------------------------
 'Joe''s' 'a' 'contains' 'lexeme' 'quote' 'the'
```

Optionally, integer *positions* can be attached to lexemes:

```
SELECT 'a:1 fat:2 cat:3 sat:4 on:5 a:6 mat:7 and:8 ate:9 a:10 fat:11 rat:12'::tsvector;
                                tsvector
-------------------------------------------------------------------------------
 'a':1,6,10 'and':8 'ate':9 'cat':3 'fat':2,11 'mat':7 'on':5 'rat':12 'sat':4
```

A position normally indicates the source word's location in the document. Positional information can be used for *proximity ranking*. Position values can range from 1 to 16383; larger numbers are silently set to 16383. Duplicate positions for the same lexeme are discarded.

Lexemes that have positions can further be labeled with a *weight*, which can be `A`, `B`, `C`, or `D`. `D` is the default and hence is not shown on output:

```
SELECT 'a:1A fat:2B,4C cat:5D'::tsvector;
          tsvector
----------------------------
 'a':1A 'cat':5 'fat':2B,4C
```

Weights are typically used to reflect document structure, for example by marking title words differently from body words. Text search ranking functions can assign different priorities to the different weight markers.

It is important to understand that the `tsvector` type itself does not perform any normalization; it assumes the words it is given are normalized appropriately for the application. For example,

```
select 'The Fat Rats'::tsvector;
      tsvector
--------------------
 'Fat' 'Rats' 'The'
```

For most English-text-searching applications the above words would be considered non-normalized, but tsvector doesn't care. Raw document text should usually be passed through `to_tsvector` to normalize the words appropriately for searching:

```
SELECT to_tsvector('english', 'The Fat Rats');
   to_tsvector
-----------------
 'fat':2 'rat':3
```

tsquery

A `tsquery` value stores lexemes that are to be searched for, and combines them honoring the Boolean operators `&` (AND), `|` (OR), and `!` (NOT). Parentheses can be used to enforce grouping of the operators:

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```
SELECT 'fat & rat'::tsquery;
    tsquery
---------------
 'fat' & 'rat'

SELECT 'fat & (rat | cat)'::tsquery;
          tsquery
----------------------------
 'fat' & ( 'rat' | 'cat' )

SELECT 'fat & rat & ! cat'::tsquery;
        tsquery
------------------------
 'fat' & 'rat' & !'cat'
```

In the absence of parentheses, `!` (NOT) binds most tightly, and `&` (AND) binds more tightly than `|` (OR).

Optionally, lexemes in a `tsquery` can be labeled with one or more weight letters, which restricts them to match only `tsvector` lexemes with matching weights:

```
SELECT 'fat:ab & cat'::tsquery;
    tsquery
------------------
 'fat':AB & 'cat'
```

Also, lexemes in a `tsquery` can be labeled with * to specify prefix matching:

```
SELECT 'super:*'::tsquery;
  tsquery
-----------
 'super':*
```

This query will match any word in a `tsvector` that begins with "super". Note that prefixes are first processed by text search configurations, which means this comparison returns true:

```
SELECT to_tsvector( 'postgraduate' ) @@ to_tsquery( 'postgres:*' );
 ?column?
----------
 t
(1 row)
```

because `postgres` gets stemmed to `postgr`:

```
SELECT to_tsquery('postgres:*');
 to_tsquery
------------
 'postgr':*
(1 row)
```

which then matches `postgraduate`.

Quoting rules for lexemes are the same as described previously for lexemes in `tsvector`; and, as with `tsvector`, any required normalization of words must be done before converting to the `tsquery` type. The `to_tsquery` function is convenient for performing such normalization:

```
SELECT to_tsquery('Fat:ab & Cats');
    to_tsquery
------------------
 'fat':AB & 'cat'
```

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7.2.4 Range Types

Range types are data types representing a range of values of some element type (called the range's subtype). For instance, ranges of `timestamp` might be used to represent the ranges of time that a meeting room is reserved. In this case the data type is `tsrange` (short for "timestamp range"), and `timestamp` is the subtype. The subtype must have a total order so that it is well-defined whether element values are within, before, or after a range of values.

Range types are useful because they represent many element values in a single range value, and because concepts such as overlapping ranges can be expressed clearly. The use of time and date ranges for scheduling purposes is the clearest example; but price ranges, measurement ranges from an instrument, and so forth can also be useful.

Parent topic: Data Types

Built-in Range Types

WarehousePG comes with the following built-in range types:

- `int4range` -- Range of `integer`
- `int8range` -- Range of `bigint`
- `numrange` -- Range of `numeric`
- `tsrange` -- Range of `timestamp without time zone`
- `tstzrange` -- Range of `timestamp with time zone`
- `daterange` -- Range of `date`

In addition, you can define your own range types; see CREATE TYPE for more information.

Examples

```
CREATE TABLE reservation (room int, during tsrange);
INSERT INTO reservation VALUES
    (1108, '[2010-01-01 14:30, 2010-01-01 15:30)');

-- Containment
SELECT int4range(10, 20) @> 3;

-- Overlaps
SELECT numrange(11.1, 22.2) && numrange(20.0, 30.0);

-- Extract the upper bound
SELECT upper(int8range(15, 25));

-- Compute the intersection
SELECT int4range(10, 20) * int4range(15, 25);

-- Is the range empty?
SELECT isempty(numrange(1, 5));
```

See Range Functions and Operators for complete lists of operators and functions on range types.

Inclusive and Exclusive Bounds

Every non-empty range has two bounds, the lower bound and the upper bound. All points between these values are included in the range. An inclusive bound means that the boundary point itself is included in the range as well, while an exclusive bound means that the boundary point is not included in the range.

In the text form of a range, an inclusive lower bound is represented by `[` while an exclusive lower bound is represented by `(` . Likewise, an inclusive upper bound is represented by `]` , while an exclusive upper bound is represented by `)` . (See Range Functions and Operators for more details.)

The functions `lower_inc` and `upper_inc` test the inclusivity of the lower and upper bounds of a range value, respectively.

Infinite (Unbounded) Ranges

The lower bound of a range can be omitted, meaning that all points less than the upper bound are included in the range. Likewise, if the upper bound of the range is omitted, then all points greater than the lower bound are included in the range. If both lower and upper bounds are omitted, all values of the element type are considered to be in the range.

This is equivalent to considering that the lower bound is "minus infinity", or the upper bound is "plus infinity", respectively. But note that these infinite values are never values of the range's element type, and can never be part of the range. (So there is no such thing as an inclusive infinite bound -- if you try to write one, it will automatically be converted to an exclusive bound.)

Also, some element types have a notion of "infinity", but that is just another value so far as the range type mechanisms are concerned. For example, in timestamp ranges, `[today,]` means the same thing as `[today,)` . But `[today,infinity]` means something different from `[today,infinity)` -- the latter excludes the special `timestamp` value `infinity` .

The functions `lower_inf` and `upper_inf` test for infinite lower and upper bounds of a range, respectively.

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Range Input/Output

The input for a range value must follow one of the following patterns:

```
(<lower-bound>,<upper-bound>)
(<lower-bound>,<upper-bound>]
[<lower-bound>,<upper-bound>)
[<lower-bound>,<upper-bound>]
empty
```

The parentheses or brackets indicate whether the lower and upper bounds are exclusive or inclusive, as described previously. Notice that the final pattern is `empty`, which represents an empty range (a range that contains no points).

The lower-bound may be either a string that is valid input for the subtype, or empty to indicate no lower bound. Likewise, upper-bound may be either a string that is valid input for the subtype, or empty to indicate no upper bound.

Each bound value can be quoted using `"` (double quote) characters. This is necessary if the bound value contains parentheses, brackets, commas, double quotes, or backslashes, since these characters would otherwise be taken as part of the range syntax. To put a double quote or backslash in a quoted bound value, precede it with a backslash. (Also, a pair of double quotes within a double-quoted bound value is taken to represent a double quote character, analogously to the rules for single quotes in SQL literal strings.) Alternatively, you can avoid quoting and use backslash-escaping to protect all data characters that would otherwise be taken as range syntax. Also, to write a bound value that is an empty string, write `""`, since writing nothing means an infinite bound.

Whitespace is allowed before and after the range value, but any whitespace between the parentheses or brackets is taken as part of the lower or upper bound value. (Depending on the element type, it might or might not be significant.)

Examples:

```
-- includes 3, does not include 7, and does include all points in between
SELECT '[3,7)'::int4range;

-- does not include either 3 or 7, but includes all points in between
SELECT '(3,7)'::int4range;

-- includes only the single point 4
SELECT '[4,4]'::int4range;

-- includes no points (and will be normalized to 'empty')
SELECT '[4,4)'::int4range;
```

Constructing Ranges

Each range type has a constructor function with the same name as the range type. Using the constructor function is frequently more convenient than writing a range literal constant, since it avoids the need for extra quoting of the bound values. The constructor function accepts two or three arguments. The two-argument form constructs a range in standard form (lower bound inclusive, upper bound exclusive), while the three-argument form constructs a range with bounds of the form specified by the third argument. The third argument must be one of the strings `()`, `(]`, `[)`, or `[]`. For example:

```
-- The full form is: lower bound, upper bound, and text argument indicating
-- inclusivity/exclusivity of bounds.
SELECT numrange(1.0, 14.0, '(]');

-- If the third argument is omitted, '[)' is assumed.
SELECT numrange(1.0, 14.0);

-- Although '(]' is specified here, on display the value will be converted to
-- canonical form, since int8range is a discrete range type (see below).
SELECT int8range(1, 14, '(]');

-- Using NULL for either bound causes the range to be unbounded on that side.
SELECT numrange(NULL, 2.2);
```

Discrete Range Types

A discrete range is one whose element type has a well-defined “step”, such as `integer` or `date`. In these types two elements can be said to be adjacent, when there are no valid values between them. This contrasts with continuous ranges, where it's always (or almost always) possible to identify other element values between two given values. For example, a range over the `numeric` type is continuous, as is a range over `timestamp`. (Even though `timestamp` has limited precision, and so could theoretically be treated as discrete, it's better to consider it continuous since the step size is normally not of interest.)

Another way to think about a discrete range type is that there is a clear idea of a “next” or “previous” value for each element value. Knowing that, it is possible to convert between inclusive and exclusive representations of a range's bounds, by choosing the next or previous element value instead of the one originally given. For example, in an integer range type `[4,8]` and `(3,9)` denote the same set of values; but this would not be so for a range over numeric.

A discrete range type should have a *canonicalization* function that is aware of the desired step size for the element type. The canonicalization function is charged with converting equivalent values of the range type to have identical representations, in particular consistently inclusive or exclusive bounds. If a canonicalization function is not specified, then ranges with different formatting will always be treated as unequal, even though they might represent the same set of values in reality.

The built-in range types `int4range`, `int8range`, and `daterange` all use a canonical form that includes the lower bound and excludes the upper bound; that is, `[)`. User-defined range types can use other conventions, however.

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Defining New Range Types

Users can define their own range types. The most common reason to do this is to use ranges over subtypes not provided among the built-in range types. For example, to define a new range type of subtype `float8`:

```
CREATE TYPE floatrange AS RANGE (
    subtype = float8,
    subtype_diff = float8mi
);

SELECT '[1.234, 5.678]'::floatrange;
```

Because `float8` has no meaningful "step", we do not define a canonicalization function in this example.

Defining your own range type also allows you to specify a different subtype B-tree operator class or collation to use, so as to change the sort ordering that determines which values fall into a given range.

If the subtype is considered to have discrete rather than continuous values, the CREATE TYPE command should specify a `canonical` function. The canonicalization function takes an input range value, and must return an equivalent range value that may have different bounds and formatting. The canonical output for two ranges that represent the same set of values, for example the integer ranges `[1, 7]` and `[1, 8)`, must be identical. It doesn't matter which representation you choose to be the canonical one, so long as two equivalent values with different formattings are always mapped to the same value with the same formatting. In addition to adjusting the inclusive/exclusive bounds format, a canonicalization function might round off boundary values, in case the desired step size is larger than what the subtype is capable of storing. For instance, a range type over `timestamp` could be defined to have a step size of an hour, in which case the canonicalization function would need to round off bounds that weren't a multiple of an hour, or perhaps throw an error instead.

In addition, any range type that is meant to be used with GiST or SP-GiST indexes should define a subtype difference, or `subtype_diff`, function. (The index will still work without `subtype_diff`, but it is likely to be considerably less efficient than if a difference function is provided.) The subtype difference function takes two input values of the subtype, and returns their difference (i.e., X minus Y) represented as a `float8` value. In our example above, the function `float8mi` that underlies the regular `float8` minus operator can be used; but for any other subtype, some type conversion would be necessary. Some creative thought about how to represent differences as numbers might be needed, too. To the greatest extent possible, the `subtype_diff` function should agree with the sort ordering implied by the selected operator class and collation; that is, its result should be positive whenever its first argument is greater than its second according to the sort ordering.

A less-oversimplified example of a `subtype_diff` function is:

```
CREATE FUNCTION time_subtype_diff(x time, y time) RETURNS float8 AS
'SELECT EXTRACT(EPOCH FROM (x - y))' LANGUAGE sql STRICT IMMUTABLE;

CREATE TYPE timerange AS RANGE (
    subtype = time,
    subtype_diff = time_subtype_diff
);

SELECT '[11:10, 23:00]'::timerange;
```

See CREATE TYPE for more information about creating range types.

Indexing

GiST and SP-GiST indexes can be created for table columns of range types. For instance, to create a GiST index:

```
CREATE INDEX reservation_idx ON reservation USING GIST (during);
```

A GiST or SP-GiST index can accelerate queries involving these range operators: `=`, `&&`, `<@`, `@>`, `<<`, `>>`, `-|-`, `&<`, and `&>` (see Range Functions and Operators for more information).

In addition, B-tree and hash indexes can be created for table columns of range types. For these index types, basically the only useful range operation is equality. There is a B-tree sort ordering defined for range values, with corresponding `<` and `>` operators, but the ordering is rather arbitrary and not usually useful in the real world. Range types' B-tree and hash support is primarily meant to allow sorting and hashing internally in queries, rather than creation of actual indexes.

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7.3 Summary of Built-in Functions

WarehousePG supports built-in functions and operators including analytic functions and window functions that can be used in window expressions. For information about using built-in WarehousePG functions see, "Using Functions and Operators" in the *WarehousePG Administrator Guide*.

- WarehousePG Function Types
- Built-in Functions and Operators
- JSON Functions and Operators
- Window Functions
- Advanced Aggregate Functions
- Text Search Functions and Operators
- Range Functions and Operators

Parent topic: WarehousePG Reference Guide

WarehousePG Function Types

WarehousePG evaluates functions and operators used in SQL expressions. Some functions and operators are only allowed to run on the coordinator since they could lead to inconsistencies in WarehousePG segment instances. This table describes the WarehousePG Function Types.

Function Type	WarehousePG Support	Description	Comments
IMMUTABLE	Yes	Relies only on information directly in its argument list. Given the same argument values, always returns the same result.	
STABLE	Yes, in most cases	Within a single table scan, returns the same result for same argument values, but results change across SQL statements.	Results depend on database lookups or parameter values. `current_timestamp` family of functions is `STABLE`; values do not change within an execution.
VOLATILE	Restricted	Function values can change within a single table scan. For example: `random()`, `timeofday()`.	Any function with side effects is volatile, even if its result is predictable. For example: `setval()`.

In WarehousePG, data is divided up across segments — each segment is a distinct PostgreSQL database. To prevent inconsistent or unexpected results, do not run functions classified as `VOLATILE` at the segment level if they contain SQL commands or modify the database in any way. For example, functions such as `setval()` are not allowed to run on distributed data in WarehousePG because they can cause inconsistent data between segment instances.

To ensure data consistency, you can safely use `VOLATILE` and `STABLE` functions in statements that are evaluated on and run from the coordinator. For example, the following statements run on the coordinator (statements without a `FROM` clause):

```
SELECT setval('myseq', 201);
SELECT foo();
```

If a statement has a `FROM` clause containing a distributed table *and* the function in the `FROM` clause returns a set of rows, the statement can run on the segments:

```
SELECT * from foo();
```

WarehousePG does not support functions that return a table reference (`rangeFuncs`) or functions that use the `refCursor` datatype.

Built-in Functions and Operators

The following table lists the categories of built-in functions and operators supported by PostgreSQL. All functions and operators are supported in WarehousePG as in PostgreSQL with the exception of `STABLE` and `VOLATILE` functions, which are subject to the restrictions noted in WarehousePG Function Types. See the Functions and Operators section of the PostgreSQL documentation for more information about these built-in functions and operators.

Operator/Function Category	VOLATILE Functions	STABLE Functions	Restrictions
Logical Operators			
Comparison Operators			
Mathematical Functions and Operators	random setseed		
String Functions and Operators	*All built-in conversion functions*	convert pg_client_encoding	
Binary String Functions and Operators			
Bit String Functions and Operators			
Pattern Matching			
Data Type Formatting Functions		to_char to_timestamp	
Date/Time Functions and Operators	timeofday	age current_date current_time current_timestamp localtime localtimestamp now	

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Operator/Function Category	VOLATILE Functions	STABLE Functions	Restrictions
Enum Support Functions			
Geometric Functions and Operators			
Network Address Functions and Operators			
Sequence Manipulation Functions	nextval() setval()		
Conditional Expressions			
Array Functions and Operators		*All array functions*	
Aggregate Functions			
Subquery Expressions			
Row and Array Comparisons			
Set Returning Functions	generate_series		
System Information Functions		*All session information functions* *All access privilege inquiry functions* *All schema visibility inquiry functions* *All system catalog information functions* *All comment information functions* *All transaction ids and snapshots*	
System Administration Functions	set_config pg_cancel_backend pg_reload_conf pg_rotate_logfile pg_start_backup pg_stop_backup pg_size_pretty pg_ls_dir pg_read_file pg_stat_file	current_setting *All database object size functions*	> **Note** The function `pg_column_size` displays bytes required to store the value, possibly with TOAST compression.

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Operator/Function Category	VOLATILE Functions	STABLE Functions	Restrictions
		cursor_to_xml(cursor refcursor, count int, nulls boolean, tableforest boolean, targetns text) cursor_to_xmlschema(cursor refcursor, nulls boolean, tableforest boolean, targetns text) database_to_xml(nulls boolean, tableforest boolean, targetns text) database_to_xmlschema(nulls boolean, tableforest boolean, targetns text) database_to_xml_and_xmlschema(nulls boolean, tableforest boolean, targetns text) query_to_xml(query text, nulls boolean, tableforest boolean, targetns text) query_to_xmlschema(query text, nulls boolean, tableforest boolean, targetns text) query_to_xml_and_xmlschema(query text, nulls boolean, tableforest boolean, targetns text) schema_to_xml(schema name, nulls boolean, tableforest boolean, targetns text) schema_to_xmlschema(schema name, nulls boolean, tableforest boolean, targetns text) schema_to_xml_and_xmlschema(schema name, nulls boolean, tableforest boolean, targetns text) table_to_xml(tbl regclass, nulls boolean, tableforest boolean, targetns text) table_to_xmlschema(tbl regclass, nulls boolean, tableforest boolean, targetns text) table_to_xml_and_xmlschema(tbl regclass, nulls boolean, tableforest boolean, targetns text)	
XML Functions and function-like expressions		xmlagg(xml) xmlconcat(xml[, ...]) xmlelement(name name [, xmlattributes(value [AS attname] [, ...])] [, content, ...]) xmlexists(text, xml) xmlforest(content [AS name] [, ...]) xml_is_well_formed(text) xml_is_well_formed_document(text) xml_is_well_formed_content(text) xmlparse ({ DOCUMENT | CONTENT } value) xpath(text, xml) xpath(text, xml, text[]) xpath_exists(text, xml) xpath_exists(text, xml, text[]) xmlpi(name target [, content]) xmlroot(xml, version text | no value [, standalone yes|no|no value]) xmlserialize ({ DOCUMENT | CONTENT } value AS type) xml(text) text(xml) xmlcomment(xml) xmlconcat2(xml, xml)	

JSON Functions and Operators

This section describes:

- functions and operators for processing and creating JSON data
- the SQL/JSON path language

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Processing and Creating JSON Data

WarehousePG includes built-in functions and operators that create and manipulate JSON data:

- JSON Operators
- JSON Creation Functions
- JSON Aggregate Functions
- JSON Processing Functions

JSON Operators

This table describes the operators that are available for use with the `json` and `jsonb` data types.

Operator	Right Operand Type	Return Type	Description	Example	Example Result
`->`	`int`	`json` or `jsonb`	Get the JSON array element (indexed from zero, negative integers count from the end).	`'[{"a":"foo"},{"b":"bar"},{"c":"baz"}]'::json->2`	`{"c":"baz"}`
`->`	`text`	`json` or `jsonb`	Get the JSON object field by key.	`'{"a": {"b":"foo"}'::json->'a'`	`{"b":"foo"}`
`->>`	`int`	`text`	Get the JSON array element as `text`.	`'[1,2,3]'::json->>2`	`3`
`->>`	`text`	`text`	Get the JSON object field as `text`.	`'{"a":1,"b":2}'::json->>'b'`	`2`
`#>`	`text[]`	`json` or `jsonb`	Get the JSON object at the specified path.	`'{"a": {"b":{"c": "foo"}}'::json#>'{a,b}'`	`{"c": "foo"}`
`#>>`	`text[]`	`text`	Get the JSON object at the specified path as `text`.	`'{"a":[1,2,3],"b":[4,5,6]}'::json#>>'{a,2}'`	`3`

> **Note** There are parallel variants of these operators for both the `json` and `jsonb` data types. The field/element/path extraction operators return the same data type as their left-hand input (either `json` or `jsonb`), except for those specified as returning `text`, which coerce the value to `text`. The field/element/path extraction operators return `NULL`, rather than failing, if the JSON input does not have the right structure to match the request; for example if no such element exists. The field/element/path extraction operators that accept integer JSON array subscripts all support negative subscripting from the end of arrays.

These standard comparison operators are available for `jsonb`, but not for `json.` They follow the ordering rules for B-tree operations outlined at jsonb Indexing.

Operator	Description
`<`	less than
`>`	greater than
`<=`	less than or equal to
`>=`	greater than or equal to
`=`	equal
`<>` or `!=`	not equal

> **Note** The `!=` operator is converted to `<>` in the parser stage. It is not possible to implement `!=` and `<>` operators that do different things.

Operators that require the `jsonb` data type as the left operand are described in the following table. Many of these operators can be indexed by `jsonb` operator classes. For a full description of `jsonb` containment and existence semantics, refer to jsonb Containment and Existence. jsonb Indexing describes how these operators can be used to effectively index `jsonb` data.

Operator	Right Operand Type	Description	Example			
`@>`	`jsonb`	Does the left JSON value contain the right JSON path/value entries at the top level?	`'{"a":1, "b":2}'::jsonb @> '{"b":2}'::jsonb`			
`<@`	`jsonb`	Are the left JSON path/value enries contained at the top level within the right JSON value?	`'{"b":2}'::jsonb <@ '{"a":1, "b":2}'::jsonb`			
`?`	`text`	Does the *string* exist as a top-level key within the JSON value?	`'{"a":1, "b":2}'::jsonb ? 'b'`			
`?`	`text[]`	Do any of these array *strings* exist as a top-level key?	`'{"a":1, "b":2, "c":3}'::jsonb ?`	array['b', 'c']		
`?&`	`text[]`	Do all of these array *strings* exist as top-level keys?	`'["a", "b"]'::jsonb ?& array['a', 'b']`			
`||`	`jsonb`	Concatenate two `jsonb` values into a new `jsonb` value.	`'["a", "b"]'::jsonb`	`'["c", "d"]'::jsonb`		
`-`	`text`	Delete key/value pair or *string* elements from left operand. Key/value pairs are matched based on their key value.	`'{"a": "b"}'::jsonb - 'a'`			
`-`	`text[]`	Delete multiple key/value pairs or *string* elements from left operand. Key/value pairs are matched based on their key value.	`'{"a": "b", "c": "d"}'::jsonb - '{a,c}'::text[]`			
`-`	`integer`	Delete the array element with specified index (Negative integers count from the end). Throws an error if top level container is not an array.	`'["a", "b"]'::jsonb - 1`			
`#-`	`text[]`	Delete the field or element with specified path (for JSON arrays, negative integers count from the end)	`'["a", {"b":1}]'::jsonb #- '{1,b}'`			
`@?`	`jsonpath`	Does JSON path return any item for the specified JSON value?	`'{"a":[1,2,3,4,5]}'::jsonb @? '$.a[*] ? (@ > 2)'`			
`@@`	`jsonpath`	Returns the result of JSON path predicate check for the specified JSON value. Only the first item of the result is taken into account. If the result is not Boolean, then `null` is returned.	`'{"a":[1,2,3,4,5]}'::jsonb @@ '$.a[*] > 2'`			

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> **Note** The `||` operator concatenates two JSON objects by generating an object containing the union of their keys, taking the second object's value when there are duplicate keys. All other cases produce a JSON array: first, any non-array input is converted into a single-element array, and then the two arrays are concatenated. It does not operate recursively; only the top-level array or object structure is merged.

> **Note** The `@?` and `@@` operators suppress the following errors: lacking object field or array element, unexpected JSON item type, and numeric errors. This behavior might be helpful while searching over JSON document collections of varying structure.

JSON Creation Functions

This table describes the functions that create `json` and `jsonb` data type values. (There are no equivalent functions for `jsonb` for `row_to_json()` and `array_to_json()`. However, the `to_jsonb()` function supplies much the same functionality as these functions would.)

Function	Description	Example	Example Result
`to_json(anyelement)` `to_jsonb(anyelement)`	Returns the value as a `json` or `jsonb` object. Arrays and composites are converted (recursively) to arrays and objects; otherwise, if the input contains a cast from the type to `json`, the cast function is used to perform the conversion; otherwise, a scalar value is produced. For any scalar type other than a number, a Boolean, or a null value, the text representation will be used, in such a fashion that it is a valid `json` or `jsonb` value.	`to_json('Fred said "Hi."'::text)`	`"Fred said \"Hi.\""`
`array_to_json(anyarray [, pretty_bool])`	Returns the array as a JSON array. A multidimensional array becomes a JSON array of arrays. Line feeds will be added between dimension-1 elements if `pretty_bool` is true.	`array_to_json('{1,5},{99,100}'::int[])`	`[[1,5],[99,100]]`
`row_to_json(record [, pretty_bool])`	Returns the row as a JSON object. Line feeds will be added between level-1 elements if `pretty_bool` is true.	`row_to_json(row(1,'foo'))`	`{"f1":1,"f2":"foo"}`
`json_build_array(VARIADIC "any")`	Builds a possibly-heterogeneously-typed JSON array out of a `VARIADIC` argument list.	`json_build_array(1,2,'3',4,5)`	`[1, 2, "3", 4, 5]`
`json_build_object(VARIADIC "any")`	Builds a JSON object out of a `VARIADIC` argument list. The argument list is taken in order and converted to a set of key/value pairs.	`json_build_object('foo',1,'bar',2)`	`{"foo": 1, "bar": 2}`
`json_object(text[])`	Builds a JSON object out of a text array. The array must have either exactly one dimension with an even number of members, in which case they are taken as alternating key/value pairs, or two dimensions such that each inner array has exactly two elements, which are taken as a key/value pair.	`json_object('{a, 1, b, "def", c, 3.5}')` `json_object('{a, 1},{b, "def"},{c, 3.5}')`	`{"a": "1", "b": "def", "c": "3.5"}`
`json_object(keys text[], values text[])`	Builds a JSON object out of a text array. This form of `json_object` takes keys and values pairwise from two separate arrays. In all other respects it is identical to the one-argument form.	`json_object('{a, b}', '{1,2}')`	`{"a": "1", "b": "2"}`

> **Note** `array_to_json()` and `row_to_json()` have the same behavior as `to_json()` except for offering a pretty-printing option. The behavior described for `to_json()` likewise applies to each individual value converted by the other JSON creation functions.

> **Note** The hstore extension has a cast from `hstore` to `json`, so that `hstore` values converted via the JSON creation functions will be represented as JSON objects, not as primitive string values.

JSON Aggregate Functions

This table shows the functions that aggregate records to an array of JSON objects and pairs of values to a JSON object

Function	Argument Types	Return Type	Description
`json_agg(record)` `jsonb_agg(record)`	`record`	`json`	Aggregates records as a JSON array of objects.
`json_object_agg(name, value)` `jsonb_object_agg(name, value)`	`("any", "any")`	`json`	Aggregates name/value pairs as a JSON object.

JSON Processing Functions

This table shows the functions that are available for processing `json` and `jsonb` values.

Many of these processing functions and operators convert Unicode escapes in JSON strings to the appropriate single character. This is a not an issue if the input data type is `jsonb`, because the conversion was already done. However, for `json` data type input, this might result in an error being thrown as described inAbout JSON Data.

Table 8. JSON Processing Functions

Function	Return Type	Description	Example	Example Result
`json_array_length(json)` `jsonb_array_length(jsonb)`	`int`	Returns the number of elements in the outermost JSON array.	`json_array_length('[1,2,3,{"f1":1,"f2":[5,6]},4]')`	`5`

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Function	Return Type	Description	Example	Example Result

`json_each(json)`
`jsonb_each(jsonb)`
	`setof key text, value json`
	`setof key text, value jsonb`
		Expands the outermost JSON object into a set of key/value pairs.	`select * from json_each('{"a":"foo", "b":"bar"}')`	`key | value`
				`-----+-------`
				`a  | "foo"`
				`b  | "bar"`

`json_each_text(json)`
`jsonb_each_text(jsonb)`
	`setof key text, value text`	Expands the outermost JSON object into a set of key/value pairs. The returned values will be of type `text`.	`select * from json_each_text('{"a":"foo", "b":"bar"}')`	`key | value`
				`-----+-------`
				`a  | foo`
				`b  | bar`

`json_extract_path(from_json json, VARIADIC path_elems text[])` `jsonb_extract_path(from_json jsonb, VARIADIC path_elems text[])`	`json` `jsonb`	Returns the JSON value pointed to by `path_elems` (equivalent to `#>` operator).	`json_extract_path('{"f2": {"f3":1},"f4": {"f5":99,"f6":"foo"}','f4')`	`{"f5":99,"f6":"foo"}`
`json_extract_path_text(from_json json, VARIADIC path_elems text[])` `jsonb_extract_path_text(from_json jsonb, VARIADIC path_elems text[])`	`text`	Returns the JSON value pointed to by `path_elems` as text (equivalent to `#>>` operator).	`json_extract_path_text('{"f2": {"f3":1},"f4": {"f5":99,"f6":"foo"}','f4', 'f6')`	`foo`

`json_object_keys(json)`
`jsonb_object_keys(jsonb)`
	`setof text`	Returns set of keys in the outermost JSON object.	`json_object_keys('{"f1":"abc","f2":{"f3":"a", "f4":"b"}')`	`json_object_keys`
				`------------------`
				`f1`
				`f2`

`json_populate_record(base anyelement, from_json json)`
`jsonb_populate_record(base anyelement, from_json jsonb)`
	`anyelement`	Expands the object in `from_json` to a row whose columns match the record type defined by `base`. See the Note 1.	`select * from json_populate_record(null::myrowtype, '{"a": 1, "b": ["2", "a b"], "c": {"d": 4, "e": "a b c"}')`	`a |  b  |  c`
				`---+-----------+-------------`
				`1 | {2,"a b"} | (4,"a b c")`

`json_populate_recordset(base anyelement, from_json json)`
`jsonb_populate_recordset(base anyelement, from_json jsonb)`
	`setof anyelement`	Expands the outermost array of objects in `from_json` to a set of rows whose columns match the record type defined by `base`. See the Note 1.	`select * from json_populate_recordset(null::myrowtype, '[{"a":1,"b":2}, {"a":3,"b":4}]')`	`a | b`
				`---+---`
				`1 | 2`
				`3 | 4`

`json_array_elements(json)`
`jsonb_array_elements(jsonb)`
	`setof json`
	`setof jsonb`
		Expands a JSON array to a set of JSON values.	`select * from json_array_elements('[1,true, [2,false]]')`	`value`
				`-----------`
				`1`
				`true`
				`[2,false]`

`json_array_elements_text(json)`
`jsonb_array_elements_text(jsonb)`
	`setof text`	Expands a JSON array to a set of `text` values.	`select * from json_array_elements_text('["foo", "bar"]')`	`value`
				`-----------`
				`foo`
				`bar`

`json_typeof(json)` `jsonb_typeof(jsonb)`	`text`	Returns the type of the outermost JSON value as a text string. Possible types are `object`, `array`, `string`, `number`, `boolean`, and `null`.	`json_typeof('-123.4')`	`number`

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Function	Return Type	Description	Example	Example Result

`json_to_record(json)`
`jsonb_to_record(jsonb)`
	`record`	Builds an arbitrary record from a JSON object. See the Note 1.
		As with all functions returning record, the caller must explicitly define the structure of the record with an `AS` clause.
			`select * from json_to_record('{"a":1,"b":[1,2,3],"c":[1,2,3],"e":"bar","r": {"a": 123, "b": "a b c"}}') as x(a int, b text, c int[], d text, r myrowtype)`	`a | b | c | d | r`
				`---+---------+---------+---+---------------`
				`1 | [1,2,3] | {1,2,3} | | (123,"a b c")`

`json_to_recordset(json)`
`jsonb_to_recordset(jsonb)`
	`setof record`	Builds an arbitrary set of records from a JSON array of objects See the Note 1.
		As with all functions returning record, the caller must explicitly define the structure of the record with an `AS` clause.
			`select * from json_to_recordset('[{"a":1,"b":"foo"},{"a":"2","c":"bar"}]') as x(a int, b text);`	`a | b`
				`---+-----`
				`1 | foo`
				`2 |`

`json_strip_nulls(from_json json)` `jsonb_strip_nulls(from_json jsonb)`	`json` `jsonb`	Returns *from_json* with all object fields that have null values omitted. Other null values are untouched.	`json_strip_nulls('[{"f1":1,"f2":null},2,null,3]')`	`[{"f1":1},2,null,3]`
`jsonb_set(target jsonb, path text[], new_value jsonb [, create_missing boolean])`	`jsonb`	Returns *target* with the section designated by *path* replaced by *new_value*, or with *new_value* added if *create_missing* is true (default is `true`) and the item designated by *path* does not exist. As with the path oriented operators, negative integers that appear in *path* count from the end of JSON arrays.	`jsonb_set('[{"f1":1,"f2":null},2,null,3]', '{0,f1}','[2,3,4]', false)` `jsonb_set('[{"f1":1,"f2":null},2]', '{0,f3}','[2,3,4]')`	`[{"f1":[2,3,4],"f2":null},2,null,3]` `[{"f1": 1, "f2": null, "f3": [2, 3, 4]}, 2]`
`jsonb_insert(target jsonb, path text[], new_value jsonb [, insert_after boolean])`	`jsonb`	Returns *target* with *new_value* inserted. If *target* section designated by *path* is in a JSONB array, *new_value* will be inserted before target or after if *insert_after* is true (default is `false`). If *target* section designated by *path* is in JSONB object, *new_value* will be inserted only if *target* does not exist. As with the path oriented operators, negative integers that appear in *path* count from the end of JSON arrays.	`jsonb_insert('{"a": [0,1,2]}', '{a, 1}', '"new_value"')` `jsonb_insert('{"a": [0,1,2]}', '{a, 1}', '"new_value"', true)`	`{"a": [0, "new_value", 1, 2]}` `{"a": [0, 1, "new_value", 2]}`

`jsonb_pretty(from_json jsonb)`	`text`	Returns *from_json* as indented JSON text.	`jsonb_pretty('[{"f1":1,"f2":null},2,null,3]')`	`[`
				`{`
				`"f1": 1,`
				`"f2": null`
				`},`
				`2,`
				`null,`
				`3`
				`]`

`jsonb_path_exists(target jsonb, path jsonpath [, vars jsonb [, silent bool]])`	`boolean`	Checks whether JSON path returns any item for the specified JSON value.	`jsonb_path_exists('{"a": [1,2,3,4,5]}', '$.a[*] ? (@ >= $min && @ <= $max)', '{"min":2,"max":4}')`	`true`
`jsonb_path_match(target jsonb, path jsonpath [, vars jsonb [, silent bool]])`	`boolean`	Returns the result of JSON path predicate check for the specified JSON value. Only the first item of the result is taken into account. If the result is not Boolean, then `null` is returned.	`jsonb_path_match('{"a": [1,2,3,4,5]}', 'exists($.a[*] ? (@ >= $min && @ <= $max))', '{"min":2,"max":4}')`	`true`

`jsonb_path_query(target jsonb, path jsonpath [, vars jsonb [, silent bool]])`	`setof jsonb`	Gets all JSON items returned by JSON path for the specified JSON value.	`select * from jsonb_path_query('{"a": [1,2,3,4,5]}', '$.a[*] ? (@ >= $min && @ <= $max)', '{"min":2,"max":4}');`	`jsonb_path_query`
				`------------------`
				`2`
				`3`
				`4`

`jsonb_path_query_array(target jsonb, path jsonpath [, vars jsonb [, silent bool]])`	`jsonb`	Gets all JSON items returned by JSON path for the specified JSON value and wraps result into an array.	`jsonb_path_query_array('{"a": [1,2,3,4,5]}', '$.a[*] ? (@ >= $min && @ <= $max)', '{"min":2,"max":4}')`	`[2, 3, 4]`

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Function	Return Type	Description	Example	Example Result
`jsonb_path_query_first(target jsonb, path jsonpath [, vars jsonb [, silent bool]])`	`jsonb`	Gets the first JSON item returned by JSON path for the specified JSON value. Returns `NULL` on no results.	`jsonb_path_query_first('{"a":[1,2,3,4,5]}', '$.a[*] ? (@ >= $min && @ <= $max)', '{"min":2,"max":4}')`	`2`

Notes on JSON processing functions examples

1. The functions `json[b]_populate_record()`, `json[b]_populate_recordset()`, `json[b]_to_record()` and `json[b]_to_recordset()` operate on a JSON object, or array of objects, and extract the values associated with keys whose names match column names of the output row type. Object fields that do not correspond to any output column name are ignored, and output columns that do not match any object field will be filled with nulls. To convert a JSON value to the SQL type of an output column, the following rules are applied in sequence:

    - A JSON null value is converted to a SQL null in all cases.
    - If the output column is of type `json` or `jsonb`, the JSON value is just reproduced exactly.
    - If the output column is a composite (row) type, and the JSON value is a JSON object, the fields of the object are converted to columns of the output row type by recursive application of these rules.
    - Likewise, if the output column is an array type and the JSON value is a JSON array, the elements of the JSON array are converted to elements of the output array by recursive application of these rules.
    - Otherwise, if the JSON value is a string literal, the contents of the string are fed to the input conversion function for the column's data type.
    - Otherwise, the ordinary text representation of the JSON value is fed to the input conversion function for the column's data type.

    While the examples for these functions use constants, the typical use would be to reference a table in the `FROM` clause and use one of its `json` or `jsonb` columns as an argument to the function. Extracted key values can then be referenced in other parts of the query, like `WHERE` clauses and target lists. Extracting multiple values in this way can improve performance over extracting them separately with per-key operators.

2. All the items of the `path` parameter of `jsonb_set()` as well as `jsonb_insert()` except the last item must be present in the target. If `create_missing` is false, all items of the `path` parameter of `jsonb_set()` must be present. If these conditions are not met the target is returned unchanged.

    If the last path item is an object key, it will be created if it is absent and given the new value. If the last path item is an array index, if it is positive the item to set is found by counting from the left, and if negative by counting from the right - `-1` designates the rightmost element, and so on. If the item is out of the range -array_length .. array_length -1, and create_missing is true, the new value is added at the beginning of the array if the item is negative, and at the end of the array if it is positive.

3. The `json_typeof` function's `null` return value should not be confused with a SQL NULL. While calling `json_typeof('null'::json)` will return `null`, calling `json_typeof(NULL::json)` will return a SQL NULL.

4. If the argument to `json_strip_nulls()` contains duplicate field names in any object, the result could be semantically somewhat different, depending on the order in which they occur. This is not an issue for `jsonb_strip_nulls()` since `jsonb` values never have duplicate object field names.

5. The `jsonb_path_exists()`, `jsonb_path_match()`, `jsonb_path_query()`, `jsonb_path_query_array()`, and `jsonb_path_query_first()` functions have optional `vars` and `silent` arguments.

    If the `vars` argument is specified, it provides an object containing named variables to be substituted into a `jsonpath` expression.

    If the `silent` argument is specified and has the `true` value, these functions suppress the same errors as the `@?` and `@@` operators.

The SQL/JSON Path Language

SQL/JSON path expressions specify the items to be retrieved from the JSON data, similar to XPath expressions used for SQL access to XML. In WarehousePG, path expressions are implemented as the `jsonpath` data type and can use any elements described in jsonpath Type.

JSON query functions and operators pass the provided path expression to the *path engine* for evaluation. If the expression matches the queried JSON data, the corresponding SQL/JSON item is returned. Path expressions are written in the SQL/JSON path language and can also include arithmetic expressions and functions. Query functions treat the provided expression as a text string, so it must be enclosed in single quotes.

A path expression consists of a sequence of elements allowed by the `jsonpath` data type. The path expression is evaluated from left to right, but you can use parentheses to change the order of operations. If the evaluation is successful, a sequence of SQL/JSON items (*SQL/JSON sequence*) is produced, and the evaluation result is returned to the JSON query function that completes the specified computation.

To refer to the JSON data to be queried (the *context item*), use the `$` sign in the path expression. It can be followed by one or more accessor operators, which go down the JSON structure level by level to retrieve the content of context item. Each operator that follows deals with the result of the previous evaluation step.

For example, suppose you have some JSON data from a GPS tracker that you would like to parse, such as:

```
{
  "track": {
    "segments": [
      {
        "location"[ 47.763, 13.4034 ],
        "start time": "2018-10-14 10:05:14",
        "HR": 73
      },
      {
        "location"[ 47.706, 13.2635 ],
        "start time": "2018-10-14 10:39:21",
        "HR": 135
      }
    ]
  }
}
```

To retrieve the available track segments, you need to use the `.<key>` accessor operator for all the preceding JSON objects:

```
'$.track.segments'
```

If the item to retrieve is an element of an array, you have to unnest this array using the `[*]` operator. For example, the following path will return location coordinates for all the available track segments:

```
'$.track.segments[*].location'
```

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To return the coordinates of the first segment only, you can specify the corresponding subscript in the `[]` accessor operator. Note that the SQL/JSON arrays are 0-relative:

```
'$.track.segments[0].location'
```

The result of each path evaluation step can be processed by one or more `jsonpath` operators and methods listed in SQL/JSON Path Operators and Methods below. Each method name must be preceded by a dot. For example, you can get an array size:

```
'$.track.segments.size()'
```

For more examples of using `jsonpath` operators and methods within path expressions, see SQL/JSON Path Operators and Methods below.

When defining the path, you can also use one or more *filter expressions* that work similar to the `WHERE` clause in SQL. A filter expression begins with a question mark and provides a condition in parentheses:

```
? (condition)
```

Filter expressions must be specified right after the path evaluation step to which they are applied. The result of this step is filtered to include only those items that satisfy the provided condition. SQL/JSON defines three-valued logic, so the condition can be `true`, `false`, or `unknown`. The `unknown` value plays the same role as SQL `NULL` and can be tested for with the is `unknown` predicate. Further path evaluation steps use only those items for which filter expressions return `true`.

Functions and operators that can be used in filter expressions are listed in jsonpath Filter Expression Elements. The path evaluation result to be filtered is denoted by the `@` variable. To refer to a JSON element stored at a lower nesting level, add one or more accessor operators after `@`.

Suppose you would like to retrieve all heart rate values higher than 130. You can achieve this using the following expression:

```
'$.track.segments[*].HR ? (@ > 130)'
```

To get the start time of segments with such values instead, you have to filter out irrelevant segments before returning the start time, so the filter expression is applied to the previous step, and the path used in the condition is different:

```
'$.track.segments[*] ? (@.HR > 130)."start time"'
```

You can use several filter expressions on the same nesting level, if required. For example, the following expression selects all segments that contain locations with relevant coordinates and high heart rate values:

```
'$.track.segments[*] ? (@.location[1] < 13.4) ? (@.HR > 130)."start time"'
```

Using filter expressions at different nesting levels is also allowed. The following example first filters all segments by location, and then returns high heart rate values for these segments, if available:

```
'$.track.segments[*] ? (@.location[1] < 13.4).HR ? (@ > 130)'
```

You can also nest filter expressions within each other:

```
'$.track ? (exists(@.segments[*] ? (@.HR > 130))).segments.size()'
```

This expression returns the size of the track if it contains any segments with high heart rate values, or an empty sequence otherwise.

Deviations from Standard

WarehousePG's implementation of SQL/JSON path language has the following deviations from the SQL/JSON standard:

- `.datetime()` item method is not implemented yet mainly because immutable `jsonpath` functions and operators cannot reference session timezone, which is used in some datetime operations. Datetime support will be added to `jsonpath` in future versions of WarehousePG.
- A path expression can be a Boolean predicate, although the SQL/JSON standard allows predicates only in filters. This is necessary for implementation of the `@@` operator. For example, the following `jsonpath` expression is valid in WarehousePG:

  ```
  '$.track.segments[*].HR < 70'
  ```

- There are minor differences in the interpretation of regular expression patterns used in `like_regex` filters as described in Regular Expressions.

Strict And Lax Modes

When you query JSON data, the path expression may not match the actual JSON data structure. An attempt to access a non-existent member of an object or element of an array results in a structural error. SQL/JSON path expressions have two modes of handling structural errors:

- lax (default) — the path engine implicitly adapts the queried data to the specified path. Any remaining structural errors are suppressed and converted to empty SQL/JSON sequences.
- strict — if a structural error occurs, an error is raised.

The lax mode facilitates matching of a JSON document structure and path expression if the JSON data does not conform to the expected schema. If an operand does not match the requirements of a particular operation, it can be automatically wrapped as an SQL/JSON array or unwrapped by converting its elements into an SQL/JSON sequence before performing this operation. Besides, comparison operators automatically unwrap their operands in the lax mode, so you can compare SQL/JSON arrays out-of-the-box. An array of size 1 is considered equal to its sole element. Automatic unwrapping is not performed only when:

- The path expression contains `type()` or `size()` methods that return the type and the number of elements in the array, respectively.
- The queried JSON data contain nested arrays. In this case, only the outermost array is unwrapped, while all the inner arrays remain unchanged. Thus, implicit unwrapping can only go one level down within each path evaluation step.

For example, when querying the GPS data listed above, you can abstract from the fact that it stores an array of segments when using the lax mode:

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```
'lax $.track.segments.location'
```

In the strict mode, the specified path must exactly match the structure of the queried JSON document to return an SQL/JSON item, so using this path expression will cause an error. To get the same result as in the lax mode, you have to explicitly unwrap the segments array:

```
'strict $.track.segments[*].location'
```

The `.**` accessor can lead to surprising results when using the lax mode. For instance, the following query selects every HR value twice:

```
lax $.**.HR
```

This happens because the `.**` accessor selects both the segments array and each of its elements, while the `.HR` accessor automatically unwraps arrays when using the lax mode. To avoid surprising results, we recommend using the `.**` accessor only in the strict mode. The following query selects each HR value just once:

```
strict $.**.HR
```

Regular Expressions

SQL/JSON path expressions allow matching text to a regular expression with the `like_regex` filter. For example, the following SQL/JSON path query would case-insensitively match all strings in an array that starts with an English vowel:

```
'$[*] ? (@ like_regex "^[aeiou]" flag "i")'
```

The optional flag string may include one or more of the characters `i` for case-insensitive match, `m` to allow `^` and `$` to match at newlines, `s` to allow `.` to match a newline, and `q` to quote the whole pattern (reducing the behavior to a simple substring match).

The SQL/JSON standard borrows its definition for regular expressions from the `LIKE_REGEX` operator, which in turn uses the XQuery standard. WarehousePG does not currently support the `LIKE_REGEX` operator. Therefore, the `like_regex` filter is implemented using the POSIX regular expression engine as described in POSIX Regular Expressions. This leads to various minor discrepancies from standard SQL/JSON behavior which are catalogued in Differences From XQuery (LIKE_REGEX). Note, however, that the flag-letter incompatibilities described there do not apply to SQL/JSON, as it translates the XQuery flag letters to match what the POSIX engine expects.

Keep in mind that the pattern argument of `like_regex` is a JSON path string literal, written according to the rules given in jsonpath Type. This means in particular that any backslashes you want to use in the regular expression must be doubled. For example, to match string values of the root document that contain only digits:

```
$.* ? (@ like_regex "^\\d+$")
```

SQL/JSON Path Operators and Methods

The following table describes the operators and methods available in `jsonpath`:

Operator/Method	Description	Example JSON	Example Query	Result
`+` (unary)	Plus operator that iterates over the SQL/JSON sequence	`{"x": [2.85, -14.7, -9.4]}`	`+ $.x.floor()`	`2, -15, -10`
`-` (unary)	Minus operator that iterates over the SQL/JSON sequence	`{"x": [2.85, -14.7, -9.4]}`	`- $.x.floor()`	`-2, 15, 10`
`+` (binary)	Addition	`[2]`	`2 + $[0]`	`4`
`-` (binary)	Subtraction	`[2]`	`4 - $[0]`	`2`
`*`	Multiplication	`[4]`	`2 * $[0]`	`8`
`/`	Division	`[8]`	`$[0] / 2`	`4`
`%`	Modulus	`[32]`	`$[0] % 10`	`2`
`type()`	Type of the SQL/JSON item	`[1, "2", {}]`	`$[*].type()`	`"number", "string", "object"`
`size()`	Size of the SQL/JSON item	`{"m": [11, 15]}`	`$.m.size()`	`2`
`double()`	Approximate floating-point number converted from an SQL/JSON number or a string	`{"len": "1.9"}`	`$.len.double() * 2`	`3.8`
`ceiling()`	Nearest integer greater than or equal to the SQL/JSON number	`{"h": 1.3}`	`$.h.ceiling()`	`2`
`floor()`	Nearest integer less than or equal to the SQL/JSON number	`{"h": 1.3}`	`$.h.floor()`	`1`
`abs()`	Absolute value of the SQL/JSON number	`{"z": -0.3}`	`$.z.abs()`	`0.3`
`keyvalue()`	Sequence of object's key-value pairs represented as array of items containing three fields (`"key"`, `"value"`, and `"id"`). `"id"` is a unique identifier of the object key-value pair belongs to.	`{"x": "20", "y": 32}`	`$.keyvalue()`	`{"key": "x", "value": "20", "id": 0}, {"key": "y", "value": 32, "id": 0}`

SQL/JSON Filter Expression Elements

The following table describes the available filter expressions elements for `jsonpath`:

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Value/Predicate	Description	Example JSON	Example Query	Result
`==`	Equality operator	`[1, 2, 1, 3]`	`$[*] ? (@ == 1)`	`1, 1`
`!=`	Non-equality operator	`[1, 2, 1, 3]`	`$[*] ? (@ != 1)`	`2, 3`
`<>`	Non-equality operator (same as `!=`)	`[1, 2, 1, 3]`	`$[*] ? (@ <> 1)`	`2, 3`
`<`	Less-than operator	`[1, 2, 3]`	`$[*] ? (@ < 2)`	`1`
`<=`	Less-than-or-equal-to operator	`[1, 2, 3]`	`$[*] ? (@ <= 2)`	`1, 2`
`>`	Greater-than operator	`[1, 2, 3]`	`$[*] ? (@ > 2)`	`3`
`>=`	Greater-than-or-equal-to operator	`[1, 2, 3]`	`$[*] ? (@ >= 2)`	`2, 3`
`true`	Value used to perform comparison with JSON `true` literal	`[{"name": "John", "parent": false}, {"name": "Chris", "parent": true}]`	`$[*] ? (@.parent == true)`	`{"name": "Chris", "parent": true}`
`false`	Value used to perform comparison with JSON `false` literal	`[{"name": "John", "parent": false}, {"name": "Chris", "parent": true}]`	`$[*] ? (@.parent == false)`	`{"name": "John", "parent": false}`
`null`	Value used to perform comparison with JSON `null` value	`[{"name": "Mary", "job": null}, {"name": "Michael", "job": "driver"}]`	`$[*] ? (@.job == null) .name`	`"Mary"`
`&&`	Boolean AND	`[1, 3, 7]`	`$[*] ? (@ > 1 && @ < 5)`	`3`
`||`	Boolean OR	`[1, 3, 7]`	`$[*] ? (@ < 1 || @ > 5)`	`7`
`!`	Boolean NOT	`[1, 3, 7]`	`$[*] ? (!(@ < 5))`	`7`
`like_regex`	Tests whether the first operand matches the regular expression given by the second operand, optionally with modifications described by a string of `flag` characters.	`["abc", "abd", "aBdC", "abdacb", "babc"]`	`$[*] ? (@ like_regex "^ab.*c" flag "i")`	`"abc", "aBdC", "abdacb"`
`starts with`	Tests whether the second operand is an initial substring of the first operand	`["John Smith", "Mary Stone", "Bob Johnson"]`	`$[*] ? (@ starts with "John")`	`"John Smith"`
`exists`	Tests whether a path expression matches at least one SQL/JSON item	`{"x": [1, 2], "y": [2, 4]}`	`strict $.* ? (exists (@ ? (@[*] > 2)))`	`2, 4`
`is unknown`	Tests whether a Boolean condition is `unknown`	`[-1, 2, 7, "infinity"]`	`$[*] ? ((@ > 0) is unknown)`	`"infinity"`

Window Functions

The following are WarehousePG built-in window functions. All window functions are *immutable*. For more information about window functions, see "Window Expressions" in the *WarehousePG Administrator Guide*.

Function	Return Type	Full Syntax	Description	
`cume_dist()`	`double precision`	`CUME_DIST() OVER ( [PARTITION BY` expr `] ORDER BY` expr `)`	Calculates the cumulative distribution of a value in a group of values. Rows with equal values always evaluate to the same cumulative distribution value.	
`dense_rank()`	`bigint`	`DENSE_RANK () OVER ( [PARTITION BY` expr `] ORDER BY` expr `)`	Computes the rank of a row in an ordered group of rows without skipping rank values. Rows with equal values are given the same rank value.	
`first_value(*expr*)`	same as input expr type	`FIRST_VALUE(` expr `) OVER ( [PARTITION BY` expr `] ORDER BY` expr `[ROWS`	RANGE `frame\_expr`])`	Returns the first value in an ordered set of values.
`lag(*expr* [,*offset*] [,*default*])`	same as input *expr* type	`LAG(` *expr* `[,` *offset* `] [,` *default* `]) OVER ( [PARTITION BY` *expr* `] ORDER BY` *expr* `)`	Provides access to more than one row of the same table without doing a self join. Given a series of rows returned from a query and a position of the cursor, `LAG` provides access to a row at a given physical offset prior to that position. The default `offset` is 1. *default* sets the value that is returned if the offset goes beyond the scope of the window. If *default* is not specified, the default value is null.	
`last_value(*expr*)`	same as input *expr* type	`LAST_VALUE(`*expr*`) OVER ( [PARTITION BY` *expr*`] ORDER BY` *expr* `[ROWS`	RANGE *frame_expr*])`	Returns the last value in an ordered set of values.
`lead(*expr* [,*offset*] [,*default*])`	same as input *expr* type	`LEAD(*expr*[,*offset*] [,*expr**default*]) OVER ( [PARTITION BY *expr*] ORDER BY *expr* )`	Provides access to more than one row of the same table without doing a self join. Given a series of rows returned from a query and a position of the cursor, `lead` provides access to a row at a given physical offset after that position. If *offset* is not specified, the default offset is 1. *default* sets the value that is returned if the offset goes beyond the scope of the window. If *default* is not specified, the default value is null.	
`ntile(*expr*)`	`bigint`	`NTILE(*expr*) OVER ( [PARTITION BY *expr*] ORDER BY *expr* )`	Divides an ordered data set into a number of buckets (as defined by *expr*) and assigns a bucket number to each row.	
`percent_rank()`	`double precision`	`PERCENT_RANK () OVER ( [PARTITION BY *expr*] ORDER BY *expr*)`	Calculates the rank of a hypothetical row `R` minus 1, divided by 1 less than the number of rows being evaluated (within a window partition).	
`rank()`	`bigint`	`RANK () OVER ( [PARTITION BY *expr*] ORDER BY *expr*)`	Calculates the rank of a row in an ordered group of values. Rows with equal values for the ranking criteria receive the same rank. The number of tied rows are added to the rank number to calculate the next rank value. Ranks may not be consecutive numbers in this case.	
`row_number()`	`bigint`	`ROW_NUMBER () OVER ( [PARTITION BY *expr*] ORDER BY *expr*)`	Assigns a unique number to each row to which it is applied (either each row in a window partition or each row of the query).	

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Advanced Aggregate Functions

The following built-in advanced analytic functions are WarehousePG extensions of the PostgreSQL database. Analytic functions are *immutable*.

Note The WarehousePG MADlib Extension for Analytics provides additional advanced functions to perform statistical analysis and machine learning with WarehousePG data. See MADlib Extension for Analytics.

Table 10. Advanced Aggregate Functions

Function	Return Type	Full Syntax	Description

`gp_array_agg (anyarray)`	same as the argument data type	`gp_array_agg (anyarray)`
		Example:
		`CREATE TABLE intarr_tbl (a int, arr int[]);`
		`INSERT INTO intarr_tbl SELECT i, array[i, i] FROM generate_series(1, 5)i;`
		`INSERT INTO intarr_tbl SELECT 6, '{6, NULL}'::int[];`
		`INSERT INTO intarr_tbl SELECT 8, '{NULL, 7}'::int[];`
		`SELECT gp_array_agg(arr ORDER BY arr) FROM intarr_tbl;`
			A parallel version of `array_agg(anyarray)`. Concatenates input arrays to create an array of one higher dimension. The inputs must all have the same dimensions, and they cannot be empty or null.

`gp_array_agg (anynonarray)`	array of the argument type	`gp_array_agg (anynonarray)`
		Example:
		`CREATE TABLE table1(a int4, b int4);`
		`INSERT INTO table1 VALUES (4,5), (2,1), (1,3), (3,null), (3,7);`
		`SELECT gp_array_agg(a ORDER BY b NULLS FIRST) FROM table1;`
			An parallel version of `array_agg(anynonarray)`. Creates an array by concatenating input values, including nulls.

`MEDIAN (expr)`	`timestamp, timestamptz, interval, float`	`MEDIAN (expression)`
		Example:
		`SELECT department_id, MEDIAN(salary)`
		`FROM employees`
		`GROUP BY department_id;`
			Can take a two-dimensional array as input. Treats such arrays as matrices.

`PERCENTILE_CONT (expr) WITHIN GROUP (ORDER BY expr [DESC/ASC])`	`timestamp, timestamptz, interval, float`	`PERCENTILE_CONT(percentage) WITHIN GROUP (ORDER BY expression)`
		Example:
		`SELECT department_id,`
		`PERCENTILE_CONT (0.5) WITHIN GROUP (ORDER BY salary DESC)`
		`"Median_cont";`
		`FROM employees GROUP BY department_id;`
			Performs an inverse distribution function that assumes a continuous distribution model. It takes a percentile value and a sort specification and returns the same datatype as the numeric datatype of the argument. This returned value is a computed result after performing linear interpolation. Null are ignored in this calculation.

`PERCENTILE_DISC (expr) WITHIN GROUP (ORDER BY expr [DESC/ASC])`	`timestamp, timestamptz, interval, float`	`PERCENTILE_DISC(percentage) WITHIN GROUP (ORDER BY expression)`
		Example:
		`SELECT department_id,`
		`PERCENTILE_DISC (0.5) WITHIN GROUP (ORDER BY salary DESC)`
		`"Median_desc";`
		`FROM employees GROUP BY department_id;`
			Performs an inverse distribution function that assumes a discrete distribution model. It takes a percentile value and a sort specification. This returned value is an element from the set. Null are ignored in this calculation.

`sum(array[])`	`smallint[]int[], bigint[], float[]`	`sum(array[[1,2],[3,4]])`
		Example:
		`CREATE TABLE mymatrix (myvalue int[]);`
		`INSERT INTO mymatrix VALUES (array[[1,2],[3,4]]);`
		`INSERT INTO mymatrix VALUES (array[[0,1],[1,0]]);`
		`SELECT sum(myvalue) FROM mymatrix;`
		` sum`
		`---------------`
		` {1,3},{4,4}`
			Performs matrix summation. Can take as input a two-dimensional array that is treated as a matrix.

`pivot_sum (label[], label, expr)`	`int[], bigint[], float[]`	`pivot_sum( array['A1','A2'], attr, value)`	A pivot aggregation using sum to resolve duplicate entries.
`unnest (array[])`	set of `anyelement`	`unnest( array['one', 'row', 'per', 'item'])`	Transforms a one dimensional array into rows. Returns a set of `anyelement`, a polymorphic pseudotype in PostgreSQL.

Text Search Functions and Operators

The following tables summarize the functions and operators that are provided for full text searching. See Using Full Text Search for a detailed explanation of WarehousePG's text search facility.

Operator	Description	Example	Result

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Operator	Description	Example	Result
`@@`	`tsvector` matches `tsquery` ?	`to_tsvector('fat cats ate rats') @@ to_tsquery('cat & rat')`	`t`
`@@@`	deprecated synonym for `@@`	`to_tsvector('fat cats ate rats') @@@ to_tsquery('cat & rat')`	`t`
`		`	concatenate `tsvector` s	`'a':1 b:2'::tsvector	'c:1 d:2 b:3'::tsvector`	`'a':1 'b':2,5 'c':3 'd':4`
`&&`	AND `tsquery` s together	`'fat	rat'::tsquery && 'cat'::tsquery`	`('fat'	'rat') & 'cat'`
`		`	OR `tsquery` s together	`'fat	rat'::tsquery	'cat'::tsquery`	`('fat' | 'rat')	'cat'`
`!!`	negate a `tsquery`	`!! 'cat'::tsquery`	`!'cat'`
`@>`	`tsquery` contains another ?	`'cat'::tsquery @> 'cat & rat'::tsquery`	`f`
`<@`	`tsquery` is contained in ?	`'cat'::tsquery <@ 'cat & rat'::tsquery`	`t`

Note The `tsquery` containment operators consider only the lexemes listed in the two queries, ignoring the combining operators.

In addition to the operators shown in the table, the ordinary B-tree comparison operators (=, <, etc) are defined for types `tsvector` and `tsquery`. These are not very useful for text searching but allow, for example, unique indexes to be built on columns of these types.

Function	Return Type	Description	Example	Result
`get_current_ts_config()`	regconfig	get default text search configuration	get_current_ts_config()	english
`length(tsvector)`	integer	number of lexemes in tsvector	length('fat:2,4 cat:3 rat:5A'::tsvector)	3
`numnode(tsquery)`	integer	number of lexemes plus operators in tsquery	numnode('(fat & rat) | cat'::tsquery)	5
`plainto_tsquery([ config regconfig , ] querytext)`	tsquery	produce tsquery ignoring punctuation	plainto_tsquery('english', 'The Fat Rats')	'fat' & 'rat'
`querytree(query tsquery)`	text	get indexable part of a tsquery	querytree('foo & ! bar'::tsquery)	'foo'
`setweight(tsvector, "char")`	tsvector	assign weight to each element of tsvector	setweight('fat:2,4 cat:3 rat:5B'::tsvector, 'A')	'cat':3A 'fat':2A,4A 'rat':5A
`strip(tsvector)`	tsvector	remove positions and weights from tsvector	strip('fat:2,4 cat:3 rat:5A'::tsvector)	'cat' 'fat' 'rat'
`to_tsquery([ config regconfig , ] query text)`	tsquery	normalize words and convert to tsquery	to_tsquery('english', 'The & Fat & Rats')	'fat' & 'rat'
`to_tsvector([ config regconfig , ] documenttext)`	tsvector	reduce document text to tsvector	to_tsvector('english', 'The Fat Rats')	'fat':2 'rat':3
`ts_headline([ config regconfig, ] documenttext, query tsquery [, options text ])`	text	display a query match	ts_headline('x y z', 'z'::tsquery)	x y z
`ts_rank([ weights float4[], ] vector tsvector,query tsquery [, normalization integer ])`	float4	rank document for query	ts_rank(textsearch, query)	0.818
`ts_rank_cd([ weights float4[], ] vectortsvector, query tsquery [, normalizationinteger ])`	float4	rank document for query using cover density	ts_rank_cd('{0.1, 0.2, 0.4, 1.0}', textsearch, query)	2.01317
`ts_rewrite(query tsquery, target tsquery,substitute tsquery)`	tsquery	replace target with substitute within query	ts_rewrite('a & b'::tsquery, 'a'::tsquery, 'foo|bar'::tsquery)	'b' & ('foo' | 'bar')
`ts_rewrite(query tsquery, select text)`	tsquery	replace using targets and substitutes from a SELECTcommand	SELECT ts_rewrite('a & b'::tsquery, 'SELECT t,s FROM aliases')	'b' & ('foo' | 'bar')
`tsvector_update_trigger()`	trigger	trigger function for automatic tsvector column update	CREATE TRIGGER ... tsvector_update_trigger(tsvcol, 'pg_catalog.swedish', title, body)	
`tsvector_update_trigger_column()`	trigger	trigger function for automatic tsvector column update	CREATE TRIGGER ... tsvector_update_trigger_column(tsvcol, configcol, title, body)	

Note All the text search functions that accept an optional `regconfig` argument will use the configuration specified by default_text_search_config when that argument is omitted.

The functions in the following table are listed separately because they are not usually used in everyday text searching operations. They are helpful for development and debugging of new text search configurations.

Function	Return Type	Description	Example	Result
`ts_debug([ *config* regconfig, ] *document* text, OUT *alias* text, OUT *description* text, OUT *token* text, OUT *dictionaries* regdictionary[], OUT *dictionary* regdictionary, OUT *lexemes* text[])`	`setof record`	test a configuration	`ts_debug('english', 'The Brightest supernovaes')`	`(asciiword,"Word, all ASCII",The, {english_stem},english_stem, {}) ...`
`ts_lexize(*dict* regdictionary, *token* text)`	`text[]`	test a dictionary	`ts_lexize('english_stem', 'stars')`	`{star}`
`ts_parse(*parser\_name* text, *document* text, OUT *tokid* integer, OUT *token* text)`	`setof record`	test a parser	`ts_parse('default', 'foo - bar')`	`(1,foo) ...`
`ts_parse(*parser\_oid* oid, *document* text, OUT *tokid* integer, OUT *token* text)`	`setof record`	test a parser	`ts_parse(3722, 'foo - bar')`	`(1,foo) ...`

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Function	Return Type	Description	Example	Result
`ts_token_type(*parser\_name* text, OUT *tokid* integer, OUT *alias* text, OUT description text)`	`setof record`	get token types defined by parser	`ts_token_type('default')`	`(1,asciiword,"Word, all ASCII") ...`
`ts_token_type(*parser\_oid* oid, OUT *tokid* integer, OUT *alias* text, OUT *description* text)`	`setof record`	get token types defined by parser	`ts_token_type(3722)`	`(1,asciiword,"Word, all ASCII") ...`
`ts_stat(*sqlquery* text, [ *weights* text, ] OUT *word* text, OUT *ndocinteger*, OUT *nentry* integer)`	`setof record`	get statistics of a tsvectorcolumn	`ts_stat('SELECT vector from apod')`	`(foo,10,15) ...`

Range Functions and Operators

See Range Types for an overview of range types.

The following table shows the operators available for range types.

Operator	Description	Example	Result
`=`	equal	`int4range(1,5) = '[1,4]'::int4range`	`t`
`<>`	not equal	`numrange(1.1,2.2) <> numrange(1.1,2.3)`	`t`
`<`	less than	`int4range(1,10) < int4range(2,3)`	`t`
`>`	greater than	`int4range(1,10) > int4range(1,5)`	`t`
`<=`	less than or equal	`numrange(1.1,2.2) <= numrange(1.1,2.2)`	`t`
`>=`	greater than or equal	`numrange(1.1,2.2) >= numrange(1.1,2.0)`	`t`
`@>`	contains range	`int4range(2,4) @> int4range(2,3)`	`t`
`@>`	contains element	`'[2011-01-01,2011-03-01)'::tsrange @> '2011-01-10'::timestamp`	`t`
`<@`	range is contained by	`int4range(2,4) <@ int4range(1,7)`	`t`
`<@`	element is contained by	`42 <@ int4range(1,7)`	`f`
`&&`	overlap (have points in common)	`int8range(3,7) && int8range(4,12)`	`t`
`<<`	strictly left of	`int8range(1,10) << int8range(100,110)`	`t`
`>>`	strictly right of	`int8range(50,60) >> int8range(20,30)`	`t`
`&<`	does not extend to the right of	`int8range(1,20) &< int8range(18,20)`	`t`
`&>`	does not extend to the left of	`int8range(7,20) &> int8range(5,10)`	`t`
`-`	-`	is adjacent to	`numrange(1.1,2.2) - - numrange(2.2,3.3)`	`t`
`+`	union	`numrange(5,15) + numrange(10,20)`	`[5,20)`
`*`	intersection	`int8range(5,15) * int8range(10,20)`	`[10,15)`
`-`	difference	`int8range(5,15) - int8range(10,20)`	`[5,10)`

The simple comparison operators `<`, `>`, `<=`, and `>=` compare the lower bounds first, and only if those are equal, compare the upper bounds. These comparisons are not usually very useful for ranges, but are provided to allow B-tree indexes to be constructed on ranges.

The left-of/right-of/adjacent operators always return false when an empty range is involved; that is, an empty range is not considered to be either before or after any other range.

The union and difference operators will fail if the resulting range would need to contain two disjoint sub-ranges, as such a range cannot be represented.

The following table shows the functions available for use with range types.

Function	Return Type	Description	Example	Result
`lower(anyrange)`	range's element type	lower bound of range	`lower(numrange(1.1,2.2))`	`1.1`
`upper(anyrange)`	range's element type	upper bound of range	`upper(numrange(1.1,2.2))`	`2.2`
`isempty(anyrange)`	`boolean`	is the range empty?	`isempty(numrange(1.1,2.2))`	`false`
`lower_inc(anyrange)`	`boolean`	is the lower bound inclusive?	`lower_inc(numrange(1.1,2.2))`	`true`
`upper_inc(anyrange)`	`boolean`	is the upper bound inclusive?	`upper_inc(numrange(1.1,2.2))`	`false`
`lower_inf(anyrange)`	`boolean`	is the lower bound infinite?	`lower_inf('(,)'::daterange)`	`true`
`upper_inf(anyrange)`	`boolean`	is the upper bound infinite?	`upper_inf('(,)'::daterange)`	`true`
`range_merge(anyrange, anyrange)`	`anyrange`	the smallest range which includes both of the given ranges	`range_merge('[1,2)'::int4range, '[3,4)'::int4range)`	`[1,4)`

The `lower` and `upper` functions return null if the range is empty or the requested bound is infinite. The `lower_inc`, `upper_inc`, `lower_inf`, and `upper_inf` functions all return false for an empty range.

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7.4 Additional Supplied Modules

WarehousePG (WHPG) extends the core capabilities of Postgres with a suite of additional modules designed for enterprise-scale data warehousing. These modules provide specialized functionality for performance, security, and integration, and are categorized into three primary types:

- **Postgres Sourced Modules**: These are standard "contrib" modules that are part of the official PostgreSQL distribution. WarehousePG includes these to ensure developers can use familiar, high-quality Postgres tools for data manipulation and query analysis.
- **WHPG Open Source Modules**: These are open-source extensions specifically developed or optimized for the WarehousePG MPP ecosystem.
- **EDB Provided Modules**: These are specialized enhancements provided by EDB to deliver enterprise-grade security, governance, and support for business-critical environments.

The following WarehousePG and PostgreSQL `contrib` modules are installed; refer to the linked module documentation for usage instructions.

- auto_explain Provides a means for logging execution plans of slow statements automatically.
- btree_gin - Provides sample generalized inverted index (GIN) operator classes that implement B-tree equivalent behavior for certain data types.
- citext - Provides a case-insensitive, multibyte-aware text data type.
- dblink - Provides connections to other WarehousePGs.
- diskquota - Allows administrators to set disk usage quotas for WarehousePG roles and schemas.
- fuzzystrmatch - Determines similarities and differences between strings.
- gp_exttable_fdw - Built-in foreign-data wrapper that internally converts an external table to a foreign table.
- gp_legacy_string_agg - Implements a legacy, single-argument `string_agg()` aggregate function that was present in WarehousePG 5.
- gp_sparse_vector - Implements a WarehousePG data type that uses compressed storage of zeros to make vector computations on floating point numbers faster.
- hstore - Provides a data type for storing sets of key/value pairs within a single PostgreSQL value.
- ip4r - Provides data types for operations on IPv4 and IPv6 IP addresses.
- ltree - Provides data types for representing labels of data stored in a hierarchical tree-like structure.
- orafce - Provides WarehousePG-specific Oracle SQL compatibility functions.
- pageinspect - Provides functions for low level inspection of the contents of database pages; available to superusers only.
- pg_buffercache - Provides access to five views for obtaining cluster-wide shared buffer metrics.
- pg_cron - Provides a cron-based job scheduler that runs inside the database.
- pg_stat_statements - Provides a means for tracking execution statistics of all SQL statements executed by WarehousePG.
- pg_trgm - Provides functions and operators for determining the similarity of alphanumeric text based on trigram matching. The module also provides index operator classes that support fast searching for similar strings.
- pgcrypto - Provides cryptographic functions for WarehousePG.
- postgresml - Provides functions for using tens of thousands of pre-trained open source AI/machine learning models in WarehousePG.
- postgres_fdw - Provides a foreign data wrapper (FDW) for accessing data stored in an external PostgreSQL or WarehousePG.
- postgresql-hll - Provides HyperLogLog data types for PostgreSQL and WarehousePG.
- sslinfo - Provides information about the SSL certificate that the current client provided when connecting to WarehousePG.
- tablefunc - Provides various functions that return tables (multiple rows).
- timestamp9 - Provides an efficient nanosecond-precision timestamp data type for WarehousePG.
- tsm_system_rows - Implements the `SYSTEM_ROWS` table sampling method.
- tsm_system_time - implements the `SYSTEM_TIME` table sampling method.
- uuid-ossp - Provides functions to generate universally unique identifiers (UUIDs).

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7.4.1 EDB provided modules

EDB-provided modules deliver a suite of enterprise-grade extensions specifically engineered to enhance the security, performance, and manageability of your WarehousePG cluster. Backed by 24x7 expert support, these modules ensure your environment meets the rigorous demands of business-critical, petabyte-scale data warehousing.

EDB provides the following modules:

- PGAA - Enables distributed analytical queries against object storage directly from WarehousePG, with support for Parquet, Delta Lake, and Iceberg formats.
- pgAudit - Provides detailed session and object audit logging for WarehousePG.
- PGFS - Provides the storage layer for object storage connectivity, including credential management for S3, GCS, and Azure. Required dependency of PGAA.
- pgvector - Provides vector similarity search capabilities for WarehousePG that enable searching, storing, and querying machine language-generated embeddings at large scale.
- user_profile - Provides password quality checking and policy definition for WarehousePG.
- whpg-anonymizer - Provides dynamic data masking and static data anonymization for WarehousePG.
- whpg_fdw - Provides a foreign data wrapper (FDW) for accessing data stored in a remote WarehousePG cluster.

Downloading and installing an extension

You must install the extension on each host in your WarehousePG cluster.

1. From the coordinator, download the package from the EDB repository:

````
```bash
export EDB_SUBSCRIPTION_TOKEN=<your-token>
export EDB_REPO=gpsupp
curl -1sSLf "https://downloads.enterprisedb.com/$EDB_SUBSCRIPTION_TOKEN/$EDB_REPO/setup.rpm.sh" | sudo -E bash
sudo dnf download edb-whpg<major_version>-<extension_name>
```




```bash
export EDB_SUBSCRIPTION_TOKEN=<your-token>
export EDB_REPO=gpsupp
curl -1sSLf "https://downloads.enterprisedb.com/$EDB_SUBSCRIPTION_TOKEN/$EDB_REPO/setup.rpm.sh" | sudo -E bash
sudo yumdownloader edb-whpg<major_version>-<extension_name>
```




Where:
- `<your-token>` is the token you received when you registered for the EDB subscription.
- `<major_version>` is your WHPG version (6 or 7).
- `<extension_name>` is the name of the extension you want to install.
````

1. Create a file `all_hosts` on your WHPG coordinator, which lists all hosts in the WHPG cluster. For example:

   ```
   cdw
   scdw
   sdw1
   sdw2
   sdw3
   ```

2. From the coordinator, use the `gpsync` utility to transfer the package to all hosts in the cluster and then use the `gpssh` utility to install the package:

````
```bash
gpsync -f all_hosts <package-name> =:/tmp
gpssh -f all_hosts -e 'sudo dnf install -y /tmp/<package-name>'
```




```bash
gpsync -f all_hosts <package-name> =:/tmp
gpssh -f all_hosts -e 'sudo yum install -y /tmp/<package-name>'
```
````

Where `<package-name>` is the name of the package file you downloaded.

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7.4.1.1 Postgres Analytics Accelerator (PGAA)

The Postgres Analytics Accelerator (PGAA) extension enables WarehousePG to run distributed analytical queries directly against data in object storage, without requiring ETL or data movement into the cluster. PGAA supports Parquet, Delta Lake, and Iceberg formats, and integrates with Iceberg REST catalogs and Apache Spark.

PGAA requires the PGFS extension as a dependency, which is installed automatically when you install PGAA.

Installing PGAA

For full installation instructions, including prerequisites, package names, and cluster configuration, seeInstalling PGAA on WarehousePG.

Using PGAA

For guidance on querying object storage, connecting to Iceberg catalogs, and accelerating queries with Spark, see Scaling with WarehousePG.

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7.4.1.2 pgAudit

The PostgreSQL Audit Extension (pgAudit) provides detailed session and object audit logging via the standard PostgreSQL logging facility. It produces the forensic audit trails required to comply with various government, financial, and ISO certifications.

While standard PostgreSQL statement logging (`log_statement = all`) provides a basic history, it often lacks the granular detail required for deep forensics. pgAudit focuses on the specific internal actions taken by the database to satisfy a request, rather than just the request itself.

Downloading, installing, and loading the extension

Refer to Downloading and installing an extension for installation and setup instructions.

Once installed, you must load the pgAudit extension as a shared library before you can use it within your databases.

1. Load the extension as a shared library before you can use it within your databases. Check for existing shared libraries:

```
gpconfig -s
shared_preload_libraries
```

2. Use the output of the previous command to enable the new extension, along any other shared libraries, and restart WHPG:

```
gpconfig -c shared_preload_libraries -v '<other_libraries>,
pgAudit'
gpstop -ar
```

3. Create the extension in your database:

```
CREATE EXTENSION
pgaudit;
```

Configuring pgAudit settings

These settings control pgAudit behavior and can only be modified by a superuser. Settings can be applied globally (via `postgresql.conf` or using `ALTER SYSTEM`), at the database level (`ALTER DATABASE`), or at the role level (`ALTER ROLE`).

- `pgaudit.log` : Specifies the classes of statements to log. The supported values are:
    - `READ` : `SELECT` and `COPY` when the source is a relation or a query.
    - `WRITE` : `INSERT` , `UPDATE` , `DELETE` , `TRUNCATE` , and `COPY` when the target is a relation.
    - `FUNCTION` : Function calls and DO blocks.
    - `ROLE` : Statements related to roles and privileges, such as `GRANT` , `REVOKE` , `CREATE/ALTER/DROP ROLE` .
    - `DDL` : All other DDL statements not included in the `ROLE` class.
    - `MISC` : Miscellaneous commands, such as `DISCARD` , `FETCH` , `CHECKPOINT` , `VACUUM` , and `SET` .
    - `MISC_SET` : Miscellaneous `SET` commands. For example, `SET ROLE` .
    - `ALL` : Include all of the above.
    - `NONE` : (Default) Log nothing.
- `pgaudit.log_catalog` : Logs statements where all relations are in `pg_catalog` . Default is `on` . Disable this setting to reduce system noise.
- `pgaudit.log_client` : Determines if audit messages are visible to the client process, such as `psql` . Default is `off` . Leave this setting disabled to reduce noise, but consider enabling it for debugging purposes.
- `pgaudit.log_level` : Specifies the log level for entries. See Message Severity Levels for supported values. Note that `ERROR` , `FATAL` , and `PANIC` are not supported. This setting `pgaudit.log_level` is only enabled when `pgaudit.log_client` is enabled. The default value is `LOG` .
- `pgaudit.log_parameter` : Includes statement parameters in CSV format following the statement text. Default is `off` .
- `pgaudit.log_relation` : Creates a separate entry for each relation referenced in a statement. Enable this parameter for exhaustive logging without using object audit logging. Default is `off` .
- `pgaudit.log_statement_once` : Logs statement text only once per statement/substatement pair to reduce verbosity. Default is `off` .
- `pgaudit.role` : Specifies the master role to use for object audit logging. There is no default value.

Using pgAudit

pgAudit supports two main auditing methods: **session audit logging** and **object audit logging**.

Session audit logging

Session auditing captures statements executed by a specific user or backend. You define which classes of statements to log using the `pgaudit.log` parameter.

Examples

- Log all DDL and `WRITE` statements:

```
SET pgaudit.log = 'write,
ddl';
```

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- Create a separate log entry for every table referenced in a statement:

```
SET pgaudit.log_relation = on;
```

- Log everything except miscellaneous commands:

```
SET pgaudit.log = 'all, -
misc';
```

- Report audit log messages as `NOTICE`:

```
SET pgaudit.log_level = notice;
```

Object audit logging

Object auditing allows for granular logging of specific tables, views, or columns. This method uses the PostgreSQL role system to trigger logging, which is often more efficient for targeted tracking of sensitive data.

> **Note**
>
> pgAudit object logging only supports `SELECT`, `INSERT`, `UPDATE`, and `DELETE` statements.

To configure object audit logging:

1. Create an auditor role: Define a dedicated role for auditing and set `pgaudit.role` to include this role.

```
CREATE ROLE auditor WITH
NOLOGIN;
SET pgaudit.role =
'auditor';
```

2. Grant target permissions: Grant the `auditor` role the permissions you wish to track on objects.

```
GRANT <permission> ON <object> TO
auditor;
```

Examples

- Audit all reads on a table:

```
GRANT SELECT ON public.payroll TO
auditor;
```

- Audit updates to a specific column:

```
GRANT UPDATE (password) ON public.users TO
auditor;
```

Interpreting audit logs

Audit entries are sent to the PostgreSQL standard logger (`stderr` or `csvlog`). WarehousePG stores these logs within the `pg_log` directory of each segment's data directory. Each entry is prefixed with `AUDIT`.

A typical log entry follows this format:

```
AUDIT: SESSION,1,1,DDL,CREATE TABLE,TABLE,public.test_table,CREATE TABLE test_table (id int),<not logged>
```

The audit logs contain the following columns:

- `AUDIT_TYPE`: Indicates if the log was triggered by a `SESSION` or an `OBJECT` setting.
- `STATEMENT_ID`: A unique ID for the statement in this session (sequential). There may be multiple entries for a statement ID when more than one relation is logged.
- `SUBSTATEMENT_ID`: Sequential ID for sub-statements (e.g., function calls within a query).
- `CLASS`: The category of the statement, defined by `pgaudit.log` (`READ`, `WRITE`, `DDL`, etc.).
- `COMMAND`: The specific SQL command executed.
- `OBJECT_TYPE`: Type of object accessed (`TABLE`, `INDEX`, `VIEW`).
- `OBJECT_NAME`: Fully-qualified name of the object.
- `STATEMENT`: The full text of the SQL query.
- `PARAMETER`: Statement parameters if `pgaudit.log_parameter` is enabled.

Usage considerations

When implementing pgAudit in your environment, keep the following operational behaviors in mind:

- **Object renaming:** When an object is renamed, pgAudit logs the event using the new name (the target name). For example, if you execute `ALTER TABLE test RENAME TO test2;`, the audit entry will record the object name as `public.test2`.
- **Duplicate entries:** Certain commands may trigger multiple log entries for a single action. For instance, creating a table with a primary key will generate independent log entries for both the table and the underlying index. However, these related entries are grouped under a single `STATEMENT_ID`, allowing you to correlate them during an audit review.
- **Superuser auditing limitations:** It is not possible to reliably audit superuser accounts with pgAudit, as superusers have the necessary permissions to modify or bypass the extension's settings. We recommend to restrict the use of superuser accounts for daily operations.
- **Automated maintenance tasks:** Operations performed by Autovacuum and Autoanalyze processes are not captured in the audit log, as they are system-level background tasks.

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- **Aborted transactions:** Statements attempted after a transaction has entered an `aborted` state (due to a previous error) are not captured by pgAudit. However the standard PostgreSQL logging facility will still record the initial error that caused the abort, along with any subsequent failed attempts, as standard `ERROR` messages.

Best practices

- **Manage log volume:** In analytical (OLAP) environments, audit logging can generate enormous volumes of data. Assess disk space and performance impact before enabling exhaustive logging on large fact tables.
- **Filter system noise:** Set `pgaudit.log_catalog = off` to prevent logging the internal queries generated by administration tools.
- **Capture prepared statements:** Set `pgaudit.log_parameter = on` to see the actual values being passed into the query.
- **Storage management:** Use object auditing for fact tables in WarehousePG. Auditing every `INSERT` in a multi-terabyte table via session auditing can exhaust disk space rapidly.

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7.4.1.3 Postgres File System (PGFS)

The Postgres File System (PGFS) extension provides the storage layer for object storage connectivity in WarehousePG. It handles credential management and abstracts access to S3, Google Cloud Storage (GCS), and Azure, and is a required dependency of the Postgres Analytics Accelerator (PGAA) extension.

Installing PGFS

PGFS is installed automatically as a dependency when you install PGAA. For full installation instructions, see Installing PGAA on WarehousePG.

Using PGFS

PGFS is used through PGAA. For full documentation, see Scaling with WarehousePG.

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7.4.1.4 pgvector

The pgvector module provides high-performance vector similarity search capabilities for WarehousePG (WHPG). By representing complex data (like text, images, or audio) as machine-learning-generated embeddings, you can perform semantic and syntactic searches at scale.

The WarehousePG pgvector module is equivalent to version 0.7.4. of the pgvector module used with PostgreSQL. SeeLimitations to understand the limitations of the WarehousePG version of the module.

Downloading, installing, and loading the extension

Refer to Downloading and installing an extension for installation and setup instructions.

Once installed, create the extension in your database:

```
CREATE EXTENSION vector;
```

About the vector types, operators, and functions

pgvector introduces the `vector` data type along with specialized index access methods `ivfflat` and `hnsw`. These tools enable both exact and approximate nearest neighbor (ANN) searches using various distance metrics.

vector data type

The `vector` data type represents an n-dimensional coordinate. Each `vector` takes `4 * dimensions + 8` bytes of storage. Each element is a single precision floating-point number (similar to the `real` type in WarehousePG), and all of the elements must be finite (no `NaN`, `Infinity`, or `-Infinity`). Vectors can have up to 16,000 dimensions.

vector operators

pgvector provides the following operators for the `vector` data type:

Operator	Description
+	Element-wise addition
-	Element-wise subtraction
*	Element-wise multiplication
<->	Euclidean distance
<#>	Negative inner product
<=>	Cosine distance

> **Note**
>
> Because WarehousePG supports only `ASC` (ascending) order, the `<#>` returns the negative inner product to ensure the smallest value appears first.

vector functions

pgvector provides the following functions for the `vector` data type:

Function name	Return type	Description
`cosine_distance(vector, vector)`	`double precision`	Computes the cosine distance
`inner_product(vector, vector)`	`double precision`	Computes the inner product
`l2_distance(vector, vector)`	`double precision`	Computes the Euclidean distance
`l1_distance(vector, vector)`	`double precision`	Computes the taxicab distance
`vector_dims(vector)`	`integer`	Returns the number of dimensions
`vector_norm(vector)`	`double precision`	Computes the Euclidean norm

vector aggregate functions

pgvector provides the following aggregate functions for the `vector` data type:

Function	Return type	Description
`avg(vector)`	`vector`	Computes the arithmetic mean
`sum(vector)`	`vector`	Computes the sum of the vector elements

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Using the pgvector module

You can use pgvector to search, store, and query embeddings in WarehousePG.

Storing embeddings

You can define `vector` columns with a specific dimension count to ensure data integrity.

- Create a table with a `vector` column with three dimensions:

```
CREATE TABLE items (id bigserial PRIMARY KEY, embedding
vector(1536));
```

- Add a column to an existing table:

```
ALTER TABLE items ADD COLUMN embedding vector(3);
```

Performing common DML operations

- Insert data:

```
INSERT INTO items (embedding) VALUES ('[1,2,3]'),
('[4,5,6]');
```

- Upsert:

```
INSERT INTO items (id, embedding) VALUES (1,
'[1,2,3]')
    ON CONFLICT (id) DO UPDATE SET embedding =
EXCLUDED.embedding;
```

- Update and delete data:

```
UPDATE items SET embedding = '[1,2,3]' WHERE id = 1;
DELETE FROM items WHERE id = 1;
```

- Insert and update data:

```
INSERT INTO items (embedding) VALUES ('[1.1, 2.2,
3.3]');
UPDATE items SET embedding = '[4.4, 5.5, 6.6]' WHERE id = 1;
```

Querying embeddings

- Get the nearest neighbors to a `vector` by L2 distance:

```
SELECT * FROM items ORDER BY embedding <-> '[3,1,2]' LIMIT 5;
```

- Get the nearest neighbors to a row:

```
SELECT * FROM items WHERE id != 1
  ORDER BY embedding <-> (SELECT embedding FROM items WHERE id = 1) LIMIT
5;
```

- Filter by a certain distance:

```
SELECT * FROM items WHERE embedding <-> '[3,1,2]' < 5;
```

Evaluating embedding distance

- Inner product (multiply by -1):

```
SELECT (embedding <#> '[3,1,2]') * -1 AS inner_product FROM
items;
```

- Cosine similarity (1 - distance):

```
SELECT 1 - (embedding <=> '[3,1,2]') AS cosine_similarity FROM
items;
```

Aggregating embeddings

- Average the vectors in a table:

```
SELECT AVG(embedding) FROM
items;
```

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- Average a group of vectors in a table:

```
SELECT category_id, AVG(embedding) FROM items GROUP BY category_id;
```

Indexing embeddings

By default, pgvector performs an exact nearest neighbor search, which guarantees perfect recall. To trade some recall for performance, you can use an Approximate Nearest Neighbor (ANN) index.

> **Note**
>
> Unlike typical indexes, adding an approximate index may change query results.

When you create an index for an embedding, you use the `lists` parameter to specify the number of clusters created during index creation. Each cluster is a partition of the data set.

For optimal search accuracy:

- Create the index after the table has data.
- Choose an appropriate `lists` value. Use `rows / 1000` for up to 1M rows and `sqrt(rows)` for over 1M rows.
- pgvector provides a `probes` parameter that you can set at query time to specify the number of regions to search during a query. When querying, specify an appropriate number of `probes`. A high number is better for recall, a low number is better for speed. A reasonable initial value is `sqrt(lists)`.

Inverted File Flat (IVFFlat) indexes

IVFFlat indexes are best for large datasets where memory is limited. It partitions vectors into clusters (lists). You can index a `vector` that has up to 2,000 dimensions.

- Create an index on the L2 distance:

```
CREATE INDEX ON items USING ivfflat (embedding vector_l2_ops) WITH (lists =
100);
```

- Create an index on the inner product:

```
CREATE INDEX ON items USING ivfflat (embedding vector_ip_ops) WITH (lists =
100);
```

- Create an index on the cosine distance:

```
CREATE INDEX ON items USING ivfflat (embedding vector_cosine_ops) WITH (lists =
100);
```

- Specify the number of `probes` (1 by default) to specify how many regions to search.

```
SET ivfflat.probes =
10;
```

- Use `SET LOCAL` inside a transaction block to set `probes` for a single query:

```
BEGIN;
SET LOCAL ivfflat.probes =
10;
SELECT ... --- your queries
COMMIT;
```

Hierarchical navigable small world (HNSW) indexes

HNSW indexes build a graph for faster search and higher recall than IVFFlat, supporting up to 2,000 dimensions.

- Create an index on the L2 distance:

```
CREATE INDEX ON items USING hnsw (embedding vector_l2_ops);
```

- Create an index on the inner product:

```
CREATE INDEX ON items USING hnsw (embedding vector_ip_ops);
```

- Create an index on the cosine distance:

```
CREATE INDEX ON items USING hnsw (embedding
vector_cosine_ops);
```

HNSW indexes support the following parameters:

- `m`: Specifies the maximum number of connections per layer (16 by default).
- `ef_construction`: Specifies the size of the dynamic candidate list for constructing the graph (64 by default).

For example:

```
CREATE INDEX ON items USING hnsw (embedding vector_l2_ops) WITH (m = 16, ef_construction =
64);
```

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You can specify a custom size for the dynamic candidate list for a search:

```
SET hnsw.ef_search =
100;
```

Higher value provides better recall at the cost of speed. The default size of the candidate list is 40. For example:

```
BEGIN;
SET LOCAL hnsw.ef_search =
100;
SELECT ... --- your queries
COMMIT;
```

Advanced usage

Parallel index creation

WarehousePG version 7.3.1 and later supports parallel index creation for HNSW and IVFFlat indexes through the `max_parallel_maintenance_workers` configuration parameter. By default, `max_parallel_maintenance_workers` is set to `2`, which allows two parallel workers to run per segment during index creation. To disable parallel workers, set `max_parallel_maintenance_workers` to `0`.

Viewing indexing progress

You can check index creation progress in WarehousePG as described in CREATE INDEX Progress Reporting:

```
SELECT phase, tuples_done, tuples_total FROM
gp_stat_progress_create_index;
```

Filtering

Index nearest neighbor queries with a `WHERE` clause:

```
SELECT * FROM items WHERE category_id = 123 ORDER BY embedding <-> '[3,1,2]' LIMIT
5;
```

For approximate search, create a partial index on the `vector` column:

```
CREATE INDEX ON items USING ivfflat (embedding vector_l2_ops) WITH (lists =
100)
    WHERE (category_id = 123);
```

Use partitioning to perform an approximate search on many different values of the `WHERE` columns:

```
CREATE TABLE items (embedding vector(3), category_id int) PARTITION BY
LIST(category_id);
```

Performing hybrid search

Use pgvector together with full-text search for a hybrid search:

```
SELECT id, content FROM items, to_tsquery('hello & search')
query
  WHERE textsearch @@ query ORDER BY ts_rank_cd(textsearch, query) DESC LIMIT 5;
```

Performance tuning and debugging

Use `EXPLAIN ANALYZE` to debug performance:

```
EXPLAIN ANALYZE SELECT * FROM items ORDER BY embedding <-> '[3,1,2]' LIMIT 5;
```

If vectors are normalized to length 1, use inner product for the best performance:

```
SELECT * FROM items ORDER BY embedding <#> '[3,1,2]' LIMIT 5;
```

To speed up queries with an index, increase the number of inverted `lists` (at the expense of recall):

```
CREATE INDEX ON items USING ivfflat (embedding vector_l2_ops) WITH (lists =
1000);
```

Limitations

pgvector for WarehousePG has the following limitations:

- The WarehousePG query optimizer (ORCA) doesn't support `ivfflat` and `hnsw` indexes. Queries using these indexes will fall back to the Postgres-based planner.
- The size of a vector index can be larger than the size of the base table.

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7.4.1.5 user_profile

WarehousePG (WHPG) allows database superusers to manage password policies and account security via the `user_profile` extension.

Downloading, installing, and loading the extension

Refer to Downloading and installing an extension for installation and setup instructions.

Once installed, you must load the user_profile extension as a shared library before you can use it within your databases.

1. Load the extension as a shared library before you can use it within your databases. Check for existing shared libraries:

```
gpconfig -s
shared_preload_libraries
```

2. Use the output of the previous command to enable the new extension, along any other shared libraries, and restart WHPG:

```
gpconfig -c shared_preload_libraries -v '<other_libraries>,
user_profile'
gpstop -ar
```

3. Create the extension in your database:

```
CREATE EXTENSION user_profile;
```

Understanding the user_profile parameters

A profile is a set of security attributes applied to a group of roles to enforce authentication rules such as password complexity, expiration, and lockout policies.

Each profile defines password management policies designed to strengthen authentication security. These profiles allow you to:

- Track failed login attempts.
- Lock accounts automatically after a specified threshold of failures.
- Enforce password expiration and grace periods for renewals.
- Define complexity requirements to ensure strong credentials.
- Restrict password reuse to prevent credential cycling.

After creating a profile, you can associate it with one or more user roles. When a user initiates a connection, the WarehousePG (WHPG) server acts as the enforcement engine, applying the specific security rules defined in the profile associated with that user's login role.

Although a single WHPG cluster can support multiple profiles, these profiles are cluster-wide resources. This means a profile is shared by all databases within the cluster; a user accessing different databases under the same cluster will always be subject to the same profile constraints.

To update your security requirements, you only need to modify the profile. The WHPG server will then automatically apply those updated standards to every user associated with that profile across the entire cluster.

By default, WHPG creates a system profile named `default`. When a new role is created, the server automatically assigns it to the `default` profile unless an alternative is explicitly specified. Upon installing the `user_profile` extension, all existing roles are retroactively assigned to the `default` profile to ensure immediate coverage. The `default` profile is a mandatory system component and cannot be deleted.

Each profile consists of several parameters that govern how passwords and logins are handled:

Parameter Name	Description	Supported values
`FAILED_LOGIN_ATTEMPTS`	The maximum number of failed login attempts permitted before the server locks the account for the duration defined by `PASSWORD_LOCK_TIME`.	`INTEGER` > 0, or `UNLIMITED` (no lockout threshold).
`PASSWORD_LOCK_TIME`	The number of days an account remains locked after exceeding `FAILED_LOGIN_ATTEMPTS`.	`NUMERIC` >= 0 (supports decimals for partial days), or `UNLIMITED` (requires superuser unlock).
`PASSWORD_LIFE_TIME`	The password's validity period in days. If used with `PASSWORD_GRACE_TIME`, the user can still connect during the grace period but must change their password before executing commands.	`NUMERIC` >= 0 (supports decimals for partial days), or `UNLIMITED` (no expiration).
`PASSWORD_GRACE_TIME`	The grace period in days starting after password expiration. During this time, users can connect but are restricted from executing commands until the password is updated.	`NUMERIC` >= 0 (supports decimals for partial days), or `UNLIMITED` (infinite grace period).
`PASSWORD_REUSE_TIME`	The minimum number of days that must pass before a previous password can be reused. Works in conjunction with `PASSWORD_REUSE_MAX`. If both parameters are set to `UNLIMITED`, there are no restrictions on password reuse.	`NUMERIC` >= 0 (supports decimals for partial days), or `UNLIMITED` (no time restriction).
`PASSWORD_REUSE_MAX`	The number of password changes required before a previous password can be reused. Works in conjunction with `PASSWORD_REUSE_TIME`. If both parameters are set to `UNLIMITED`, there are no restrictions on password reuse.	`INTEGER` >= 0, or `UNLIMITED` (no count restriction)..
`PASSWORD_MINIMUM_LENGTH`	The minimum character count required for a password.	`INTEGER` >= 1, or `UNLIMITED` (no length check).
`PASSWORD_REQUIRE_UPPER`	Enforces the inclusion of at least one uppercase character in the password string.	`TRUE` (required) or `FALSE` (optional).
`PASSWORD_REQUIRE_LOWER`	Enforces the inclusion of at least one lowercase character in the password string.	`TRUE` (required) or `FALSE` (optional).
`PASSWORD_REQUIRE_NUMBER`	Enforces the inclusion of at least one numeric character (0-9) in the password string.	`TRUE` (required) or `FALSE` (optional).
`PASSWORD_SPECIAL_CHARS`	Defines a set of special characters; the password must contain at least one character from this specified string.	A string of characters, or '' (empty string) for no restriction.

The `default` profile initially has all parameters set to `UNLIMITED` or `FALSE`.

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Creating a new profile

Use the `up_create_profile()` User Defined Function (UDF) to create a new profile:

```
up_create_profile( <profile_name>
       [<param1>, <value1>, <param2>, <value2> ... ]);
```

Where:

- `profile_name` specifies the name of the profile.
- `parameter` specifies the attribute limited by the profile.
- `value` specifies the parameter limit.

Examples

The following command creates a profile named `acctg`. The profile specifies that if a user doesn't authenticate with the correct password in five attempts, the account is locked for one day:

```
SELECT up_create_profile('acctg',
        'FAILED_LOGIN_ATTEMPTS', '5',
        'PASSWORD_LOCK_TIME', '1');
```

The following command creates a profile named `sales`. The profile specifies that a user must change their password every 90 days:

```
SELECT up_create_profile('sales',
        'PASSWORD_LIFE_TIME', '90',
        'PASSWORD_GRACE_TIME', '3');
```

The following command creates a profile named `accts`. The profile specifies that a user can't reuse a password within `180` days of the last use of the password and must change their password at least five times before reusing the password:

```
SELECT up_create_profile('accts',
        'PASSWORD_REUSE_TIME', '180',
        'PASSWORD_REUSE_MAX', '5');
```

The following command creates a profile named `resources`. When a user associated with this profile wants to change the password, the password must contain at least one number character and one special character:

```
SELECT up_create_profile('resource',
        'PASSWORD_REQUIRE_NUMBER', 'TRUE',
        'PASSWORD_SPECIAL_CHARS', '!@#$%^&*');
```

Altering a profile

Use the `up_alter_profile()` UDF to modify a user profile:

```
up_alter_profile( <profile_name>
       [<param1>, <value1>, <param2>, <value2> ... ]);
```

Where:

- `profile_name` specifies the name of the profile.
- `parameter` specifies the attribute limited by the profile. Use `name` to rename the profile.
- `value` specifies the parameter limit.

A database superuser can use the `up_alter_profile()` UDF to modify the values specified by the `default` profile.

Examples

The following command modifies a profile named `acctg_profile` to specify that if a user doesn't successfully authenticate whitin three attempts, the account is locked for one day.

```
SELECT up_alter_profile('acctg_profile',
        'FAILED_LOGIN_ATTEMPTS', '3',
        'PASSWORD_LOCK_TIME', '1');
```

The following command changes the name of `acctg_profile` to `payables_profile`:

```
SELECT up_alter_profile('acctg_profile', 'name', 'payables_profile');
```

Inspecting a profile

Use the `up_show_profile()` UDF to list one or all profiles:

```
up_show_profile( [profile_name] );
```

Where:

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- `profile_name` specifies the name of the profile. `NULL` lists all profiles.

Dropping a profile

Use the `up_drop_profile()` UDF to drop a profile:

```
up_drop_profile(<profile_name>);
```

Where:

- `profile_name` specifies the name of the profile being dropped.

You cannot drop a profile if there are one or more users associated with it.

Examples

The following command drops a profile named `acctg_profile`:

```
SELECT
up_drop_profile('acctg_profile');
```

Associating a profile with an existing role

Use the `up_alter_role_profile()` UDF to associate a profile with an existing role:

```
up_alter_role_profile(<role_name|role_id>, <profile_name>);
```

Where:

- `role_id` or `role_name` specify the role to associate the profile with.
- `profile_name` specifies the name of the profile.

Only a database superuser can use the `up_alter_role_profile()` UDF.

Each login role can have only one profile. To discover the profile that's currently associated with a login role, use the `up_show_role_info()` UDF:

```
up_show_role_info([role_name|role_id])
```

Where:

- `role_id` or `role_name` specify the specific role to show (use `NULL` to show all roles).

Examples

The following command associates a profile named `acctg` with a user named `john`:

```
SELECT up_alter_role_profile('john', 'acctg');
```

Locking and unlocking a role

A database superuser can use the `up_lock()` and `up_unlock()` UDFs to lock or unlock a role:

```
up_lock(<role_name|role_id>)
up_unlock(<role_name|role_id>)
```

Where:

- `role_name` or `role_id` specifies the role to be locked or unlocked.

Use `up_lock()` to immediately lock a user role. Once locked, a role's `LOGIN` functionality is disabled. The role remains in this locked state until a superuser restores access using the `ACCOUNT UNLOCK` clause of the `ALTER ROLE` statement (or uses the `up_unlock()` UDF).

Use the `up_unlock()` clause to unlock a role that was locked by `up_lock()`, or a role that was locked through the profile `FAILED_LOGIN_ATTEMPTS` setting.

Examples

The following command locks a role named `john`. The account remains locked until the account is unlocked by calling `up_unlock()`.

```
SELECT up_lock('john');
```

The following command unlocks a role named `john`:

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```
SELECT up_unlock('john');
```

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7.4.1.6 whpg-anonymizer

The whpg-anonymizer extension provides powerful data masking and anonymization capabilities directly within the WarehousePG (WHPG) engine. It allows organizations to conceal sensitive Personally Identifiable Information (PII) to comply with privacy regulations such as GDPR, HIPAA, and CCPA.

Data anonymization is the process of altering personal data so that individuals can no longer be identified, typically to protect user privacy. The extension supports two primary strategies for protecting data:

- **Irreversible anonymization:** Irreversibly altering data in the underlying tables.
- **Dynamic pseudonymization:** Real-time transformation of data based on the role of the user querying the database.

Downloading, installing, and loading the extension

Refer to Downloading and installing an extension for installation and setup instructions.

Once installed, you must load the whpg-anonymizer extension as a shared library before you can use it within your databases.

1. Load the extension as a shared library before you can use it within your databases. Check for existing shared libraries:

```
gpconfig -s
shared_preload_libraries
```

2. Use the output of the previous command to enable the new extension, along any other shared libraries, and restart WHPG:

```
gpconfig -c shared_preload_libraries -v '<other_libraries>,
anon'
gpstop -ar
```

3. Create the extension in your database and initialize it:

```
CREATE EXTENSION anon;
SELECT anon.init();
```

Performing dynamic masking and anonymization

To implement data masking or anonymization in WarehousePG, follow these steps:

1. **Start the masking engine:** Dynamic masking isn't active by default to prevent performance overhead on administrative tasks. Explicitly enable the dynamic masking engine for the current session or database:

```
SELECT
anon.start_dynamic_masking();
```

2. **Define the masking policies:** Use `SECURITY LABEL` statements to map specific columns to masking static values or functions.

   - **Static value masking:** This method replaces every row in a column with the exact same string.

```
SECURITY LABEL FOR anon ON COLUMN <table_name>.<column_name>
    IS 'MASKED WITH VALUE $$<replacement_text>$$';
```

   - **Functional masking:** This method uses a mathematical function to transform the original data. It allows the masked data to maintain its original format, length, or uniqueness without revealing the actual identity.

```
SECURITY LABEL FOR anon ON COLUMN <table_name>.<column_name>
IS 'MASKED WITH FUNCTION <function_name>
(<column_name>)';
```

3. **Assign subject roles:** Identify the database roles that must see masked data and label them as `MASKED`.

```
SECURITY LABEL FOR anon ON ROLE <role_name> IS 'MASKED';
```

4. **Remove or update policies:** If you need to change a rule or stop masking a specific column, use the `NULL` label or drop the rule.

```
-- Remove a masking rule from a
column
SECURITY LABEL FOR anon ON COLUMN <table_name>.<column_name> IS NULL;

-- Remove the masking requirement from a
user
SECURITY LABEL FOR anon ON ROLE <role_name> IS NULL;
```

Implementation example

The following example demonstrates how to conceal employee phone numbers and names from a specific user.

1. Enable the dynamic masking engine:

```
SELECT
anon.start_dynamic_masking();
```

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2. Create a sample table and populate it with sensitive data:

```
CREATE TABLE employees
(
    id SERIAL PRIMARY
KEY,
    name TEXT,
    phone TEXT,
    salary
NUMERIC
);

INSERT INTO employees (name, phone, salary)
VALUES
('Alice', '13812345678', 25000),
('Bob', '13987654321', 18000);
```

3. Apply a static string rule, which masks names with a static string:

```
SECURITY LABEL FOR anon ON COLUMN employees.name
IS 'MASKED WITH VALUE $$CONFIDENTIAL$$';
```

4. Apply a functional masking rule, which masks phone numbers using a partial MD5 hash:

```
SECURITY LABEL FOR anon ON COLUMN employees.phone
IS 'MASKED WITH FUNCTION
pg_catalog.substring(pg_catalog.md5(phone),0,12)';
```

5. Assign the `MASKED` label to the `analyst` role:

```
CREATE ROLE analyst
LOGIN;
GRANT SELECT ON employees TO
analyst;
SECURITY LABEL FOR anon ON ROLE analyst IS 'MASKED';
```

6. When logged in as the `analyst` role, the PII is automatically concealed:

```
SELECT * FROM employees;
id |     name     |    phone    | salary
----+--------------+-------------+--------
1 | CONFIDENTIAL | 4c0115d39dd |
25000
2 | CONFIDENTIAL | 16d4b6356cc |
18000
(2 rows)
```

Limitations

Because WarehousePG utilizes a Massively Parallel Processing (MPP) architecture, certain features of PostgreSQL `postgresql_anonymizer` are restricted.

Unsupported functions

The `anon.fake_*` family of functions, such as `anon.fake_first_name()`, is not supported in WarehousePG for dynamic masking.

These functions rely on secondary table lookups to fetch pre-generated data. In an MPP environment, segment nodes can't perform secondary relation lookups during the execution of a primary query. Attempting to use them will result in a cross-slice execution error:

```
ERROR:  function cannot execute on a QE slice because it accesses relation
<relation>
```

Standard masking functions that do not require external table lookups are fully supported. Examples include:

- `anon.random_zip()`
- `anon.random_date_between()`
- `anon.partial()`
- Standard Postgres hashing and string manipulation functions

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7.4.1.7 whpg_fdw

The WarehousePG (WHPG) `whpg_fdw` extension is a Foreign Data Wrapper (FDW) that you can use to run federated queries between two WarehousePG clusters. It allows you to query data stored in a remote WarehousePG database as if it were part of your local database.

The `whpg_fdw` extension is based on the PostgreSQL Foreign Data Wrapper framework, leveraging its capabilities to connect and interact with remote WarehousePG databases seamlessly.

Downloading, installing, and loading the extension

Refer to Downloading and installing an extension for installation and setup instructions.

Once installed, create the extension in your database:

```
CREATE EXTENSION whpg_fdw;
```

Using the extension

Perform the following tasks to access data that resides in a remote WHPG cluster with `whpg_fdw`:

1. Create a foreign server to represent each remote WHPG database to which you want to connect.
2. Create a user mapping for the local WHPG database user that you want to allow to access each server.
3. Create a foreign table for each remote WHPG table that you want to access, or import a foreign schema.
4. Import a foreign schema to import multiple foreign tables from the remote database at once.
5. Construct and run queries.

Creating a foreign server

To access a remote WarehousePG database, you must first create a foreign server which specifies the connection details of the remote database. You provide these connection parameters in the `OPTIONS` clause of the `CREATE SERVER` command. A `whpg_fdw` foreign server accepts the same options as a `postgres_fdw` foreign server. Refer to the postgres_fdw documentation for more details.

`whpg_fdw` also supports the following additional options when creating a foreign server:

- `mpp_execute`: Determines where the foreign scan is executed. The default value is `coordinator`, which means that the foreign scan runs only on the remote coordinator. Set it to `all segments` instead, to leverage the fulll Massively Parallel Processing (MPP) power of WarehousePG. This enables parallel execution across all remote segments.
- `num_segments`: Defines the number of segments in the remote cluster. This option is required only when `mpp_execute` is set to `all segments`. The default value is the total number of segments in the local WarehousePG cluster. If the local and remote clusters have different number of segments, you must manually set this value to ensure proper data distribution.
- `fetch_size`: Specifies the number of rows retrieved from the remote segments during each round trip. The default value is 100.

The following is an example of creating a `whpg_fdw` foreign server:

```
CREATE SERVER
remote_whpg
FOREIGN DATA WRAPPER
whpg_fdw
OPTIONS (host 'remote_host', port '5432', dbname
'remote_db',
         mpp_execute 'all segments', num_segments '4', fetch_size
'200');
```

Creating a user mapping

To allow your local database roles to access the remote server, you must define a user mapping that maps a local role to the credentials on the remote WarehousePG database. This follows the standard PostgreSQL Foreign Data Wrapper (FDW) syntax through the `CREATE USER MAPPING` command.

User mappings that you create can include the following `OPTIONS`:

- `user`: Specifies the name of the remote WarehousePG database user to connect as. The remote user must have the right permissions to access the required tables of the remote database.
- `password`: Specifies the password for the user. Only a superuser can connect to the remote WarehousePG database without a password.

The following is an example of creating a user mapping:

```
CREATE USER MAPPING FOR local_user
SERVER
remote_whpg
OPTIONS (user 'remote_user', password
'remote_password');
```

Creating a foreign table

Use the `CREATE FOREIGN TABLE` command to create a foreign table that represents the remote table in your local WarehousePG database.

The column data types that you specify when you create the foreign table must exactly match those in the referenced remote table. We recommend that the columns are declared with exactly the same collations, if applicable, as the referenced columns of the remote table. Because `whpg_fdw` matches foreign table columns to the remote table by name, not position, you can create a foreign table with fewer columns, or with a different column order, than the underlying remote table.

Foreign tables include the following `OPTIONS`:

- `schema_name`: Specifies the name of the schema in which the remote WarehousePG table resides.

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- `table_name` : Specifies the name of the remote WarehousePG database.

`whpg_fdw` also supports the following additional options when creating a foreign table:

- `mpp_execute` : Determines where the foreign scan is executed. The default value is the one set for the foreign server. Set this parameter to override the one specified by the foreign server creation.
- `fetch_size` : Specifies the number of rows retrieved from the remote segments during each round trip. The default value is the one set for the foreign server. Set this parameter to override the one specified by the foreign server creation.

The following is an example of creating a foreign table:

```
CREATE FOREIGN TABLE remote_table (id INT, name TEXT, age
INT)
SERVER
remote_whpg
OPTIONS (schema_name 'public', table_name 'employees');
```

Importing a foreign schema

With WarehousePG 7, you can also use the `IMPORT FOREIGN SCHEMA` command to import multiple foreign tables from the remote database at once. `whpg_fdw` supports the same options for the `IMPORT FOREIGN SCHEMA` command as `postgres_fdw` .

The following is an example of importing a foreign schema:

```
IMPORT FOREIGN SCHEMA public
FROM SERVER
remote_whpg
INTO local_schema;
```

This command creates foreign tables in the `local_schema` schema in the local database for all tables in the `public` schema in the remote database.

Constructing and running queries

Query the foreign tables using the same SQL commands as you would to query local tables. The `whpg_fdw` handles the communication with the remote WarehousePG database and retrieves the data.

```
SELECT * FROM remote_table WHERE age >
30;
```

`whpg_fdw` minimizes the data transfer between the local and remote databases by pushing down filters and projections to the remote side whenever possible. See About predicate pushdown for details. Run the `EXPLAIN VERBOSE` command to see the query plan and verify the clauses being pushed down.

```
EXPLAIN VERBOSE SELECT * FROM remote_table WHERE age >
30;
```

By default, all foreign tables created using `whpg_fdw` are updatable. You can modify this behavior by setting the `updatable` option to `false` for the foreign table or server.

> **Note**
>
> `whpg_fdw` only supports `INSERT` operations on foreign tables. `UPDATE` and `DELETE` operations are not supported.

About predicate pushdown

`whpg_fdw` for WarehousePG 7 supports predicate pushdown, which minimizes the amount of data transferred between the WarehousePG clusters by sending a query filter condition to the remote WarehousePG server where it is applied there.

> **Note**
>
> Predicate pushdown is only supported when using Postgres Planner and is not currently supported with ORCA Optimizer.

The following operations are supported for pushdown:

- `SELECT` with column projection
- `SELECT` with `WHERE` clause (filter pushdown)
- `JOIN` operations
- `LIMIT` and `OFFSET` clauses
- `ORDER BY` clause
- Aggregation functions (`MAX` , `COUNT` , `AVG` , etc.)

Limitations

- The `UPDATE` and `DELETE` operations on foreign tables are not supported.
- Pushdown for grouping sets and window aggregation is not supported.
- Triggers on foreign tables are not supported.

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7.4.2 auto_explain

The `auto_explain` module provides a means for logging execution plans of slow statements automatically, without having to run `EXPLAIN` by hand.

The WarehousePG `auto_explain` module was runs only on the WarehousePG coordinator segment host. It is otherwise equivalent in functionality to the PostgreSQL `auto_explain` module.

Loading the Module

The `auto_explain` module provides no SQL-accessible functions. To use it, simply load it into the server. You can load it into an individual session by entering this command as a superuser:

```
LOAD 'auto_explain';
```

More typical usage is to preload it into some or all sessions by including `auto_explain` in `session_preload_libraries` or `shared_preload_libraries` in `postgresql.conf`. Then you can track unexpectedly slow queries no matter when they happen. However, this does introduce overhead for all queries.

Module Documentation

See auto_explain in the PostgreSQL documentation for detailed information about the configuration parameters that control this module's behavior.

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7.4.3 btree_gin

The `btree_gin` module provides sample generalized inverted index (GIN) operator classes that implement B-tree equivalent behavior for certain data types.

The WarehousePG `btree_gin` module is equivalent to the PostgreSQL `btree_gin` module. There are no WarehousePG or MPP-specific considerations for the module.

Installing and Registering the Module

The `btree_gin` module is installed when you install WarehousePG. Before you can use any of the functions defined in the module, you must register the `btree_gin` extension in each database in which you want to use the functions:

```
CREATE EXTENSION btree_gin;
```

Refer to Installing Extensions for more information.

Module Documentation

See btree_gin in the PostgreSQL documentation for detailed information about the individual functions in this module.

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7.4.4 citext

The citext module provides a case-insensitive character string data type, `citext`. Essentially, it internally calls the `lower()` function when comparing values. Otherwise, it behaves almost exactly like the `text` data type.

The WarehousePG `citext` module is equivalent to the PostgreSQL `citext` module. There are no WarehousePG or MPP-specific considerations for the module.

Installing and Registering the Module

The `citext` module is installed when you install WarehousePG. Before you can use any of the data types, operators, or functions defined in the module, you must register the `citext` extension in each database in which you want to use the objects. Refer to Installing Extensions for more information.

Module Documentation

See citext in the PostgreSQL documentation for detailed information about the data types, operators, and functions defined in this module.

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7.4.5 dblink

The `dblink` module supports connections to other WarehousePG databases from within a database session. These databases can reside in the same WarehousePG cluster, or in a remote system.

WarehousePG supports `dblink` connections between databases in WarehousePG installations with the same major version number. You can also use `dblink` to connect to other WarehousePG installations that use compatible `libpq` libraries.

> **Note** `dblink` is intended for database users to perform short ad hoc queries in other databases. `dblink` is not intended for use as a replacement for external tables.

The WarehousePG `dblink` module is a modified version of the PostgreSQL `dblink` module. There are some restrictions and limitations when you use the module in WarehousePG.

Installing and Registering the Module

The `dblink` module is installed when you install WarehousePG. Before you can use any of the functions defined in the module, you must register the `dblink` extension in each database in which you want to use the functions. Refer to Installing Extensions for more information.

WarehousePG Considerations

In this release of WarehousePG, statements that modify table data cannot use named or implicit `dblink` connections. Instead, you must provide the connection string directly in the `dblink()` function. For example:

```
gpadmin=# CREATE TABLE testdbllocal (a int, b text) DISTRIBUTED BY (a);
CREATE TABLE
gpadmin=# INSERT INTO testdbllocal select * FROM dblink('dbname=postgres', 'SELECT * FROM testdblink') AS dbltab(id int, product text);
INSERT 0 2
```

The WarehousePG version of `dblink` deactivates the following asynchronous functions:

- `dblink_send_query()`
- `dblink_is_busy()`
- `dblink_get_result()`

Using dblink

The following procedure identifies the basic steps for configuring and using `dblink` in WarehousePG. The examples use `dblink_connect()` to create a connection to a database and `dblink()` to run an SQL query.

1. Begin by creating a sample table to query using the `dblink` functions. These commands create a small table in the `postgres` database, which you will later query from the `testdb` database using `dblink`:

   ```
   $ psql -d postgres
   psql (9.4.20)
   Type "help" for help.

   postgres=# CREATE TABLE testdblink (a int, b text) DISTRIBUTED BY (a);
   CREATE TABLE
   postgres=# INSERT INTO testdblink VALUES (1, 'Cheese'), (2, 'Fish');
   INSERT 0 2
   postgres=# \q
   $
   ```

2. Log into a different database as a superuser. In this example, the superuser `gpadmin` logs into the database `testdb`. If the `dblink` functions are not already available, register the `dblink` extension in the database:

   ```
   $ psql -d testdb
   psql (9.4beta1)
   Type "help" for help.

   testdb=# CREATE EXTENSION dblink;
   CREATE EXTENSION
   ```

3. Use the `dblink_connect()` function to create either an implicit or a named connection to another database. The connection string that you provide should be a `libpq` -style keyword/value string. This example creates a connection named `mylocalconn` to the `postgres` database on the local WarehousePG cluster:

   ```
   testdb=# SELECT dblink_connect('mylocalconn', 'dbname=postgres user=gpadmin');
    dblink_connect
   ----------------
    OK
   (1 row)
   ```

   > **Note** If a `user` is not specified, `dblink_connect()` uses the value of the `PGUSER` environment variable when WarehousePG was started. If `PGUSER` is not set, the default is the system user that started WarehousePG.

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4. Use the `dblink()` function to query a database using a configured connection. Keep in mind that this function returns a record type, so you must assign the columns returned in the `dblink()` query. For example, the following command uses the named connection to query the table you created earlier:

```
testdb=# SELECT * FROM dblink('mylocalconn', 'SELECT * FROM testdblink') AS dbltab(id int, product text);
 id | product
----+---------
  1 | Cheese
  2 | Fish
(2 rows)
```

To connect to the local database as another user, specify the `user` in the connection string. This example connects to the database as the user `test_user`. Using `dblink_connect()`, a superuser can create a connection to another local database without specifying a password.

```
testdb=# SELECT dblink_connect('localconn2', 'dbname=postgres user=test_user');
```

To make a connection to a remote database system, include host and password information in the connection string. For example, to create an implicit `dblink` connection to a remote system:

```
testdb=# SELECT dblink_connect('host=remotehost port=5432 dbname=postgres user=gpadmin password=secret');
```

Using dblink as a Non-Superuser

To make a connection to a database with `dblink_connect()`, non-superusers must include host, user, and password information in the connection string. The host, user, and password information must be included even when connecting to a local database. For example, the user `test_user` can create a `dblink` connection to the local system `cdw` with this command:

```
testdb=> SELECT dblink_connect('host=cdw port=5432 dbname=postgres user=test_user password=secret');
```

If non-superusers need to create `dblink` connections that do not require a password, they can use the `dblink_connect_u()` function. The `dblink_connect_u()` function is identical to `dblink_connect()`, except that it allows non-superusers to create connections that do not require a password.

`dblink_connect_u()` is initially installed with all privileges revoked from `PUBLIC`, making it un-callable except by superusers. In some situations, it may be appropriate to grant `EXECUTE` permission on `dblink_connect_u()` to specific users who are considered trustworthy, but this should be done with care.

> **Caution** If a WarehousePG cluster has configured users with an authentication method that does not involve a password, then impersonation and subsequent escalation of privileges can occur when a non-superuser runs `dblink_connect_u()`. The `dblink` connection will appear to have originated from the user specified by the function. For example, a non-superuser can run `dblink_connect_u()` and specify a user that is configured with `trust` authentication.

Also, even if the `dblink` connection requires a password, it is possible for the password to be supplied from the server environment, such as a `~/.pgpass` file belonging to the server's user. It is recommended that any `~/.pgpass` file belonging to the server's user not contain any records specifying a wildcard host name.

1. As a superuser, grant the `EXECUTE` privilege on the `dblink_connect_u()` functions in the user database. This example grants the privilege to the non-superuser `test_user` on the functions with the signatures for creating an implicit or a named `dblink` connection. The server and database will be identified through a standard `libpq` connection string and optionally, a name can be assigned to the connection.

   ```
   testdb=# GRANT EXECUTE ON FUNCTION dblink_connect_u(text) TO test_user;
   testdb=# GRANT EXECUTE ON FUNCTION dblink_connect_u(text, text) TO test_user;
   ```

2. Now `test_user` can create a connection to another local database without a password. For example, `test_user` can log into the `testdb` database and run this command to create a connection named `testconn` to the local `postgres` database.

   ```
   testdb=> SELECT dblink_connect_u('testconn', 'dbname=postgres user=test_user');
   ```

   > **Note** If a `user` is not specified, `dblink_connect_u()` uses the value of the `PGUSER` environment variable when WarehousePG was started. If `PGUSER` is not set, the default is the system user that started WarehousePG.

3. `test_user` can use the `dblink()` function to run a query using a `dblink` connection. For example, this command uses the `dblink` connection named `testconn` created in the previous step. `test_user` must have appropriate access to the table.

   ```
   testdb=> SELECT * FROM dblink('testconn', 'SELECT * FROM testdblink') AS dbltab(id int, product text);
   ```

Using dblink with SSL-Encrypted Connections to WarehousePG

When you use `dblink` to connect to WarehousePG over an encrypted connection, you must specify the `sslmode` property in the connection string. Set `sslmode` to at least `require` to disallow unencrypted transfers. For example:

```
testdb=# SELECT dblink_connect('greenplum_con_sales', 'dbname=sales host=gpcoordinator user=gpadmin sslmode=require');
```

Refer to SSL Client Authentication for information about configuring WarehousePG to use SSL.

Additional Module Documentation

Refer to the dblink PostgreSQL documentation for detailed information about the individual functions in this module.

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7.4.6 diskquota

The diskquota module allows WarehousePG administrators to limit the amount of disk space used by schemas, roles, or tablespaces in a database.

This topic includes the following sections:

- Installing and Registering the Module (First Use)
- About the diskquota Module
- Understanding How diskquota Monitors Disk Usage
- About the diskquota Functions and Views
- Configuring the diskquota Module
- Using the diskquota Module
- Known Issues and Limitations
- Notes
- Upgrading the Module
- Examples

Installing and Registering the Module (First Use)

The `diskquota` module is installed when you install WarehousePG.

Before you can use the module, you must perform these steps:

1. Create the `diskquota` database. The `diskquota` module uses this database to store the list of databases where the module is enabled.

   ```
   $ createdb diskquota;
   ```

2. Add the `diskquota` shared library to the WarehousePG `shared_preload_libraries` server configuration parameter and restart WarehousePG. Be sure to retain the previous setting of the configuration parameter. For example:

   ```
   $ gpconfig -s shared_preload_libraries
   Values on all segments are consistent
   GUC              : shared_preload_libraries
   Coordinator value: auto_explain
   Segment     value: auto_explain
   $ gpconfig -c shared_preload_libraries -v 'auto_explain,diskquota-2.2'
   $ gpstop -ar
   ```

3. Register the `diskquota` extension in each database in which you want to enforce disk usage quotas. You can register `diskquota` in up to ten databases.

   ```
   $ psql -d testdb -c "CREATE EXTENSION diskquota"
   ```

4. Run the `diskquota.init_table_size_table()` UDF in the database. In a database with many files, this can take some time. The `diskquota` module cannot be used until the initialization is complete.

   ```
   =# SELECT diskquota.init_table_size_table();
   ```

   > **Note** You must run the `diskquota.init_table_size_table()` UDF for `diskquota` to work.

About the diskquota Module

The disk usage for a table includes the table data, indexes, toast tables, and free space map. For append-optimized tables, the calculation includes the visibility map and index, and the block directory table.

The `diskquota` module allows a WarehousePG administrator to limit the amount of disk space used by tables in schemas or owned by roles in up to 50 databases. The administrator can also use the module to limit the amount of disk space used by schemas and roles on a per-tablespace basis, as well as to limit the disk space used per WarehousePG segment for a tablespace.

> **Note** A role-based disk quota cannot be set for the WarehousePG cluster owner (the user that creates the WarehousePG cluster).

You can set the following quotas with the `diskquota` module:

- A *schema disk quota* sets a limit on the disk space that can used by all tables in a database that reside in a specific schema. The disk usage of a schema is defined as the total of disk usage on all segments for all tables in the schema.
- A *role disk quota* sets a limit on the disk space that can be used by all tables in a database that are owned by a specific role. The disk usage for a role is defined as the total of disk usage on all segments for all tables the role owns. Although a role is a cluster-level database object, the disk usage for roles is calculated separately for each database.
- A *schema tablespace disk quota* sets a limit on the disk space that can used by all tables in a database that reside in a specific schema and tablespace.
- A *role tablespace disk quota* sets a limit on the disk space that can used by all tables in a database that are owned by a specific role and reside in a specific tablespace.
- A *per-segment tablespace disk quota* sets a limit on the disk space that can be used by a Greeplum Database segment when a tablespace quota is set for a schema or role.

Understanding How diskquota Monitors Disk Usage

A single `diskquota` launcher process runs on the active WarehousePG coordinator node. The diskquota launcher process creates and launches a diskquota worker process on the coordinator for each diskquota-enabled database. A worker process is responsible for monitoring the disk usage of tablespaces, schemas, and roles in the target database, and communicates with the WarehousePG segments to obtain the sizes of active tables. The worker process also performs quota enforcement, placing tablespaces, schemas, or roles on a denylist when they reach their quota.

When a query plan for a data-adding query is generated, and the tablespace, schema, or role into which data would be loaded is on the denylist, `diskquota` cancels the query before it starts executing, and reports an error message that the quota has been exceeded.

A query that does not add data, such as a simple `SELECT` query, is always allowed to run, even when the tablespace, role, or schema is on the denylist.

Diskquota can enforce both *soft limits* and *hard limits* for disk usage:

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- By default, `diskquota` always enforces soft limits. `diskquota` checks quotas before a query runs. If quotas are not exceeded when a query is initiated, `diskquota` allows the query to run, even if it were to eventually cause a quota to be exceeded.
- When hard limit enforcement of disk usage is enabled, `diskquota` also monitors disk usage during query execution. If a query exceeds a disk quota during execution, `diskquota` terminates the query.

  Administrators can enable enforcement of a disk usage hard limit by setting the `diskquota.hard_limit` server configuration parameter as described in Activating/Deactivating Hard Limit Disk Usage Enforcement.

There is some delay after a quota has been reached before the schema or role is added to the denylist. Other queries could add more data during the delay. The delay occurs because `diskquota` processes that calculate the disk space used by each table run periodically with a pause between executions (two seconds by default). The delay also occurs when disk usage falls beneath a quota, due to operations such as `DROP`, `TRUNCATE`, or `VACUUM FULL` that remove data. Administrators can change the amount of time between disk space checks by setting the `diskquota.naptime` server configuration parameter as described in Setting the Delay Between Disk Usage Updates.

Diskquota can operate in both *static* and *dynamic* modes:

- When the number of databases in which the `diskquota` extension is registered is less than or equal to the maximum number of `diskquota` worker processes, `diskquota` operates in static mode; it assigns a background worker (bgworker) process to monitor each database, and the bgworker process exits only when the `diskquota` extension is dropped from the database.
- When the number of databases in which the `diskquota` extension is registered is greater than the maximum number of `diskquota` worker processes, `diskquota` operates in dynamic mode. In dynamic mode, for every monitored database every `diskquota.naptime` seconds, `diskquota` creates a bgworker process to collect disk usage information for the database, and then stops the bgworker process immediately after data collection completes. In this mode, `diskquota` dynamically starts and stops bgworker processes as needed for all monitored databases.

  Administrators can change the maximum number of worker processes configured for `diskquota` by setting the `diskquota.max_workers` server configuration parameter as described in Specifying the Maximum Number of Active diskquota Worker Processes.

If a query is unable to run because the tablespace, schema, or role has been denylisted, an administrator can increase the exceeded quota to allow the query to run. The module provides views that you can use to find the tablespaces, schemas, or roles that have exceeded their limits.

About the diskquota Functions and Views

The `diskquota` module provides user-defined functions (UDFs) and views that you can use to manage and monitor disk space usage in your WarehousePG deployment.

The functions and views provided by the `diskquota` module are available in the WarehousePG schema named `diskquota`.

> **Note** You may be required to prepend the schema name (`diskquota.`) to any UDF or view that you access.

User-defined functions provided by the module include:

Function Signature	Description
void init_table_size_table()	Sizes the existing tables in the current database.
void set_role_quota(role_name text, quota text)	Sets a disk quota for a specific role in the current database. > **Note** A role-based disk quota cannot be set for the WarehousePG cluster owner.
void set_role_tablespace_quota(role_name text, tablespace_name text, quota text)	Sets a disk quota for a specific role and tablespace combination in the current database. > **Note** A role-based disk quota cannot be set for the WarehousePG cluster owner.
void set_schema_quota(schema_name text, quota text)	Sets a disk quota for a specific schema in the current database.
void set_schema_tablespace_quota(schema_name text, tablespace_name text, quota text)	Sets a disk quota for a specific schema and tablespace combination in the current database.
void set_per_segment_quota(tablespace_name text, ratio float4)	Sets a per-segment disk quota for a tablespace in the current database.
void pause()	Instructs the module to continue to count disk usage for the current database, but pause and cease emitting an error when the limit is exceeded.
void resume()	Instructs the module to resume emitting an error when the disk usage limit is exceeded in the current database.
status() RETURNS table	Displays the `diskquota` binary and schema versions and the status of soft and hard limit disk usage enforcement in the current database.

Views available in the `diskquota` module include:

View Name	Description
show_fast_database_size_view	Displays the disk space usage in the current database.
show_fast_role_quota_view	Lists active quotas for roles in the current database.
show_fast_role_tablespace_quota_view	List active quotas for roles per tablespace in the current database.
show_fast_schema_quota_view	Lists active quotas for schemas in the current database.
show_fast_schema_tablespace_quota_view	Lists active quotas for schemas per tablespace in the current database.
show_segment_ratio_quota_view	Displays the per-segment disk quota ratio for any per-segment tablespace quotas set in the current database.

Configuring the diskquota Module

`diskquota` exposes server configuration parameters that allow you to control certain module functionality:

- diskquota.naptime - Controls how frequently (in seconds) that `diskquota` recalculates the table sizes.
- diskquota.max_active_tables - Identifies the maximum number of relations (including tables, indexes, etc.) that the `diskquota` module can monitor at the same time.
- diskquota.hard_limit - Activates or deactivates the hard limit enforcement of disk usage.
- diskquota.max_workers - Specifies the maximum number of diskquota worker processes that may be running at any one time.
- diskquota.max_table_segments - Specifies the maximum number of *table segments* in the cluster.

You use the `gpconfig` command to set these parameters in the same way that you would set any WarehousePG server configuration parameter.

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Setting the Delay Between Disk Usage Updates

The `diskquota.naptime` server configuration parameter specifies how frequently (in seconds) `diskquota` recalculates the table sizes. The smaller the `naptime` value, the less delay in detecting changes in disk usage. This example sets the `naptime` to ten seconds and restarts WarehousePG:

```
$ gpconfig -c diskquota.naptime -v 10
$ gpstop -ar
```

About Shared Memory and the Maximum Number of Relations

The `diskquota` module uses shared memory to save the denylist and to save the active table list.

The denylist shared memory can hold up to one million database objects that exceed the quota limit. If the denylist shared memory fills, data may be loaded into some schemas or roles after they have reached their quota limit.

Active table shared memory holds up to one million of active tables by default. Active tables are tables that may have changed sizes since `diskquota` last recalculated the table sizes. `diskquota` hook functions are called when the storage manager on each WarehousePG segment creates, extends, or truncates a table file. The hook functions store the identity of the file in shared memory so that its file size can be recalculated the next time the table size data is refreshed.

The `diskquota.max_active_tables` server configuration parameter identifies the maximum number of relations (including tables, indexes, etc.) that the `diskquota` module can monitor at the same time. The default value is `300 * 1024`. This value should be sufficient for most WarehousePG installations. Should you change the value of this configuration parameter, you must restart the WarehousePG server.

Activating/Deactivating Hard Limit Disk Usage Enforcement

When you enable enforcement of a hard limit of disk usage, `diskquota` checks the quota during query execution. If at any point a currently running query exceeds a quota limit, `diskquota` terminates the query.

By default, hard limit disk usage enforcement is deactivated for all databases. To activate hard limit enforcement for all databases, set the `diskquota.hard_limit` server configuration parameter to `'on'`, and then reload the WarehousePG configuration:

```
$ gpconfig -c diskquota.hard_limit -v 'on'
$ gpstop -u
```

Run the following query to view the hard limit enforcement setting:

```
SELECT * from diskquota.status();
```

Specifying the Maximum Number of Active diskquota Worker Processes

The `diskquota.max_workers` server configuration parameter specifies the maximum number of diskquota worker processes (not including the `diskquota` launcher process) that may be running at any one time. The default number of maximum worker processes is `10`, and the maximum value that you can specify is `20`.

You must set this parameter at WarehousePG server start time.

> **Note** Setting `diskquota.max_workers` to a value that is larger than `max_worker_processes` has no effect; `diskquota` workers are taken from the pool of worker processes established by that WarehousePG server configuration parameter setting.

Specifying the Maximum Number of Table Segments (Shards)

A WarehousePG table (including a partitioned table's child tables) is distributed to all segments as a shard. `diskquota` counts each table shard as a *table segment*. The `diskquota.max_table_segments` server configuration parameter identifies the maximum number of *table segments* in the WarehousePG cluster, which in turn can gate the maximum number of tables that `diskquota` can monitor.

The runtime value of `diskquota.max_table_segments` equals <max_number_tables> * ⌈ {<number_segments> + 1}/{100} ⌉ * 100. The default value is `10 * 1024 * 1024`.

Using the diskquota Module

You can perform the following tasks with the `diskquota` module:

- View the diskquota Status
- Pause and Resume Disk Quota Exceeded Notifications
- Set a Schema or Role Disk Quota
- Set a Tablespace Disk Quota for a Schema or Role
- Set a Per-Segment Tablespace Disk Quota
- Display Disk Quotas and Disk Usage
- Temporarily Deactivate Disk Quota Monitoring

Viewing the diskquota Status

To view the `diskquota` module and schema version numbers, and the state of soft and hard limit enforcement in the current database, invoke the `status()` command:

```
SELECT diskquota.status();
          name          | status
------------------------+---------
 soft limits            | on
 hard limits            | on
 current binary version | 2.0.1
 current schema version | 2.0
```

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Pausing and Resuming Disk Quota Exceeded Notifications

If you do not care to be notified of disk quota exceeded events for a period of time, you can pause and resume error notification in the current database as shown below:

```
SELECT diskquota.pause();
-- perform table operations where you do not care to be notified
-- when a disk quota exceeded
SELECT diskquota.resume();
```

> **Note** The pause operation does not persist through a WarehousePG cluster restart; you must invoke `diskquota.pause()` again when the cluster is back up and running.

Setting a Schema or Role Disk Quota

Use the `diskquota.set_schema_quota()` and `diskquota.set_role_quota()` user-defined functions in a database to set, update, or delete disk quota limits for schemas and roles in the database. The functions take two arguments: the schema or role name, and the quota to set. You can specify the quota in units of MB, GB, TB, or PB; for example, `'2TB'`.

The following example sets a 250GB quota for the `acct` schema:

```
SELECT diskquota.set_schema_quota('acct', '250GB');
```

This example sets a 500MB disk quota for the `nickd` role:

```
SELECT diskquota.set_role_quota('nickd', '500MB');
```

To change a quota, invoke the `diskquota.set_schema_quota()` or `diskquota.set_role_quota()` function again with the new quota value.

To remove a schema or role quota, set the quota value to `'-1'` and invoke the function.

Setting a Tablespace Disk Quota

Use the `diskquota.set_schema_tablespace_quota()` and `diskquota.set_role_tablespace_quota()` user-defined functions in a database to set, update, or delete per-tablespace disk quota limits for schemas and roles in the current database. The functions take three arguments: the schema or role name, the tablespace name, and the quota to set. You can specify the quota in units of MB, GB, TB, or PB; for example, `'2TB'`.

The following example sets a 50GB disk quota for the tablespace named `tspaced1` and the `acct` schema:

```
SELECT diskquota.set_schema_tablespace_quota('acct', 'tspaced1', '250GB');
```

This example sets a 500MB disk quota for the `tspaced2` tablespace and the `nickd` role:

```
SELECT diskquota.set_role_tablespace_quota('nickd', 'tspaced2', '500MB');
```

To change a quota, invoke the `diskquota.set_schema_tablespace_quota()` or `diskquota.set_role_tablespace_quota()` function again with the new quota value.

To remove a schema or role tablespace quota, set the quota value to `'-1'` and invoke the function.

Setting a Per-Segment Tablespace Disk Quota

When an administrator sets a tablespace quota for a schema or a role, they may also choose to define a per-segment disk quota for the tablespace. Setting a per-segment quota limits the amount of disk space on a single WarehousePG segment that a single tablespace may consume, and may help prevent a segment's disk from filling due to data skew.

You can use the `diskquota.set_per_segment_quota()` function to set, update, or delete a per-segment tablespace disk quota limit. The function takes two arguments: the tablespace name and a ratio. The ratio identifies how much more of the disk quota a single segment can use than the average segment quota. A ratio that you specify must be greater than zero.

You can calculate the average segment quota as follows:

```
avg_seg_quota = tablespace_quota / number_of_segments
```

For example, if your WarehousePG cluster has 8 segments and you set the following schema tablespace quota:

```
SELECT diskquota.set_schema_tablespace_quota( 'accts', 'tspaced1', '800GB' );
```

The average segment quota for the `tspaced1` tablespace is `800GB / 8 = 100GB`.

If you set the following per-segment tablespace quota:

```
SELECT diskquota.set_per_segment_quota( 'tspaced1', '2.0' );
```

You can calculate the maximum allowed disk usage per segment allowed as follows:

```
max_disk_usage_per_seg = average_segment_quota * ratio
```

In this example, the maximum disk usage allowed per segment is `100GB * 2.0 = 200GB`.

`diskquota` will allow a query to run if the disk usage on all segments for all tables that are in tablespace `tblspc1` and that are goverend by a role or schema quota does not exceed `200GB`.

You can change the per-segment tablespace quota by invoking the `diskquota.set_per_segment_quota()` function again with the new quota value.

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To remove a per-segment tablespace quota, set the quota value to `'-1'` and invoke the function.

To view the per-segment quota ratio set for a tablespace, display the `show_segment_ratio_quota_view` view. For example:

```
SELECT tablespace_name, per_seg_quota_ratio
  FROM diskquota.show_segment_ratio_quota_view WHERE tablespace_name in ('tspaced1');
  tablespace_name  | per_seg_quota_ratio
-------------------+---------------------
 tspaced1          |                   2
(1 rows)
```

Identifying the diskquota-Monitored Databases

Run the following SQL commands to obtain a list of the `diskquota` -monitored databases in your WarehousePG cluster:

```
\c diskquota
SELECT d.datname FROM diskquota_namespace.database_list q, pg_database
d
    WHERE q.dbid = d.oid ORDER BY
d.datname;
```

Displaying Disk Quotas and Disk Usage

The `diskquota` module provides four views to display active quotas and the current computed disk space used.

The `diskquota.show_fast_schema_quota_view` view lists active quotas for schemas in the current database. The `nspsize_in_bytes` column contains the calculated size for all tables that belong to the schema.

```
SELECT * FROM diskquota.show_fast_schema_quota_view;
 schema_name | schema_oid | quota_in_mb | nspsize_in_bytes
-------------+------------+-------------+------------------
 acct        |      16561 |      256000 |           131072
 analytics   |      16519 |  1073741824 |        144670720
 eng         |      16560 |     5242880 |        117833728
 public      |       2200 |         250 |          3014656
(4 rows)
```

The `diskquota.show_fast_role_quota_view` view lists the active quotas for roles in the current database. The `rolsize_in_bytes` column contains the calculated size for all tables that are owned by the role.

```
SELECT * FROM diskquota.show_fast_role_quota_view;
 role_name | role_oid | quota_in_mb | rolsize_in_bytes
-----------+----------+-------------+------------------
 mdach     |    16558 |         500 |           131072
 adam      |    16557 |         300 |        117833728
 nickd     |    16577 |         500 |        144670720
(3 rows)
```

You can view the per-tablespace disk quotas for schemas and roles with the `diskquota.show_fast_schema_tablespace_quota_view` and `diskquota.show_fast_role_tablespace_quota_view` views. For example:

```
SELECT schema_name, tablespace_name, quota_in_mb, nspsize_tablespace_in_bytes
   FROM diskquota.show_fast_schema_tablespace_quota_view
   WHERE schema_name = 'acct' and tablespace_name ='tblspc1';
 schema_name | tablespace_name | quota_in_mb | nspsize_tablespace_in_bytes
-------------+-----------------+-------------+-----------------------------
 acct        | tspaced1        |      250000 |                      131072
(1 row)
```

About Temporarily Deactivating diskquota

You can temporarily deactivate the `diskquota` module by removing the shared library from `shared_preload_libraries` . For example::

```
$ gpconfig -s shared_preload_libraries
Values on all segments are consistent
GUC              : shared_preload_libraries
Coordinator value: auto_explain,diskquota-2.0
Segment     value: auto_explain,diskquota-2.0
$ gpconfig -c shared_preload_libraries -v 'auto_explain'
$ gpstop -ar
```

> **Note** When you deactivate the `diskquota` module in this manner, disk quota monitoring ceases. To re-initiate disk quota monitoring in this scenario, you must:

1. Re-add the library to `shared_preload_libraries` .
2. Restart WarehousePG.
3. Re-size the existing tables in the database by running: `SELECT diskquota.init_table_size_table();`
4. Restart WarehousePG again.

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Known Issues and Limitations

The `diskquota` module has the following limitations and known issues:

- `diskquota` does not automatically work on a segment when the segment is replaced by a mirror. You must manually restart WarehousePG in this circumstance.
- `diskquota` cannot enforce a hard limit on `ALTER TABLE ADD COLUMN DEFAULT` operations.
- If WarehousePG restarts due to a crash, you must run `SELECT diskquota.init_table_size_table();` to ensure that the disk usage statistics are accurate.
- To avoid the chance of deadlock, you must first pause the `diskquota` extension before you drop the extension in any database:

  ```
  SELECT diskquota.pause();
  DROP EXTENSION diskquota;
  ```

- `diskquota` may record an incorrect table size after `ALTER TABLESPACE`, `TRUNCATE`, or other operations that modify the `relfilenode` of the table.

  Cause: `diskquota` does not acquire any locks on a relation when computing the table size. If another session is updating the table's tablespace while `diskquota` is calculating the table size, an error can occur.

  In most cases, you can ignore the difference; `diskquota` will update the size when new data is next ingested. To immediately ensure that the disk usage statistics are accurate, invoke:

  ```
  SELECT diskquota.init_table_size_table();
  ```

  And then restart WarehousePG.

- In rare cases, a `VACUUM FULL` operation may exceed a quota limit. To remedy the situation, pause `diskquota` before the operation and then resume `diskquota` after:

  ```
  SELECT diskquota.pause();
  -- perform the VACUUM FULL
  SELECT diskquota.resume();
  ```

  If you do not want to pause/resume `diskquota`, you may choose to temporarily set a higher quota for the operation and then set it back when the `VACUUM FULL` completes. Consider the following:

  - If you `VACUUM FULL` only a single table, set the quota to be no smaller than the size of that table.
  - If you `VACUUM FULL` all tables, set the quota to be no smaller than the size of the largest table in the database.

- The size of uncommitted tables are not counted in quota views. Even though the `diskquota.show_fast_role_quota_view` view may display a smaller used quota than the quota limit, a new query may trigger a quota exceeded condition in the following circumstance:

  - Hard limit enforcement of disk usage is deactivated.
  - A long-running query in a session has consumed the full disk quota. `diskquota` does update the denylist in this scenario, but the `diskquota.show_fast_role_quota_view` may not represent the actual used quota because the long-running query is not yet committed. If you execute a new query while the original is still running, the new query will trigger a quota exceeded error.

- When `diskquota` is operating in *static mode*, it may fail to monitor some databases when `diskquota.max_workers` is greater than the available number of bgworker processes. In *dynamic mode*, `diskquota` works correctly when there is at least one available bgworker process.

Notes

The `diskquota` module can detect a newly created table inside of an uncommitted transaction. The size of the new table is included in the disk usage calculated for the corresponding schema or role. Hard limit enforcement of disk usage must enabled for a quota-exceeding operation to trigger a `quota exceeded` error in this scenario.

Deleting rows or running `VACUUM` on a table does not release disk space, so these operations cannot alone remove a schema or role from the `diskquota` denylist. The disk space used by a table can be reduced by running `VACUUM FULL` or `TRUNCATE TABLE`.

The `diskquota` module supports high availability features provided by the background worker framework. The `diskquota` launcher process only runs on the active coordinator node. The postmaster on the standby coordinator does not start the `diskquota` launcher process when it is in standby mode. When the coordinator is down and the administrator runs thegpactivatestandby command, the standby coordinator changes its role to coordinator and the `diskquota` launcher process is forked automatically. Using the `diskquota` -enabled database list in the `diskquota` database, the `diskquota` launcher creates the `diskquota` worker processes that manage disk quotas for each database.

When you expand the WarehousePG cluster, each table consumes more table segments, which may then reduce the maximum number of tables that `diskquota` can support. If you encounter the following warning, try increasing the `diskquota.max_table_segments` value, and then restart WarehousePG:

```
[diskquota] the number of tables exceeds the limit, please increase the GUC value for diskquota.max_table_segments.
```

Upgrading the Module to Version 2.x

The `diskquota` 2.2 module is installed when you install or upgrade WarehousePG. Versions 1.x, 2.0.x, and 2.1.x of the module will continue to work after you upgrade WarehousePG.

> **Note** `diskquota` will be paused during the upgrade procedure and will be automatically resumed when the upgrade completes.

Perform the following procedure to upgrade the `diskquota` module:

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1. Replace the `diskquota-<n>` shared library in the WarehousePG `shared_preload_libraries` server configuration parameter setting and restart WarehousePG. Be sure to retain the other libraries. For example:

```
$ gpconfig -s shared_preload_libraries
Values on all segments are consistent
GUC              : shared_preload_libraries
Coordinator value: auto_explain,diskquota-2.1
Segment     value: auto_explain,diskquota-2.1

$ gpconfig -c shared_preload_libraries -v 'auto_explain,diskquota-2.2'
$ gpstop -ar
```

2. Update the `diskquota` extension in every database in which you registered the module:

```
$ psql -d testdb -c "ALTER EXTENSION diskquota UPDATE TO '2.2'";
```

3. Restart WarehousePG:

```
$ gpstop -ar
```

After upgrade, your existing disk quota rules continue to be enforced, and you can define new tablespace or per-segment rules. You can also utilize the new pause/resume disk quota enforcement functions.

Examples

Setting a Schema Quota

This example demonstrates how to configure a schema quota and then observe `diskquota` soft limit behavior as data is added to the schema. The example assumes that the `diskquota` processes are configured and running.

1. Create a database named `testdb` and connect to it.

```
$ createdb testdb
$ psql -d testdb
```

2. Create the diskquota extension in the database.

```
CREATE EXTENSION diskquota;
```

3. Create a schema named `s1`:

```
CREATE SCHEMA s1;
```

4. Set a 1MB disk quota for the `s1` schema.

```
SELECT diskquota.set_schema_quota('s1', '1MB');
```

5. Run the following commands to create a table in the `s1` schema and insert a small amount of data into it. The schema has no data yet, so it is not on the denylist.

```
SET search_path TO s1;
CREATE TABLE a(i int);
INSERT INTO a SELECT generate_series(1,100);
```

6. Insert a large amount of data, enough to exceed the 1MB quota that was set for the schema. Before the `INSERT` command, the `s1` schema is still not on the denylist, so this command should be allowed to run with only soft limit disk usage enforcement in effect, even though the operation will exceed the limit set for the schema.

```
INSERT INTO a SELECT generate_series(1,10000000);
```

7. Attempt to insert a small amount of data. Because the previous command exceeded the schema's disk quota soft limit, the schema should be denylisted and any data loading command should be cancelled.

```
INSERT INTO a SELECT generate_series(1,100);
ERROR:  schema's disk space quota exceeded with name: s1
```

8. Remove the quota from the `s1` schema by setting it to `-1` and again inserts a small amount of data. A 5-second sleep before the `INSERT` command ensures that the `diskquota` table size data is updated before the command is run.

```
SELECT diskquota.set_schema_quota('s1', '-1');
-- Wait for 5 seconds to ensure that the denylist is updated
SELECT pg_sleep(5);
INSERT INTO a SELECT generate_series(1,100);
```

Enabling Hard Limit Disk Usage Enforcement and Exceeding Quota

In this example, we enable hard limit enforcement of disk usage, and re-run commands from the previous example.

1. Enable hard limit disk usage enforcement:

```
$ gpconfig -c diskquota.hard_limit -v 'on'
$ gpstop -u
```

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2. Run the following query to view the hard limit enforcement setting:

```
SELECT * from diskquota.status();
```

3. Re-set a 1MB disk quota for the `s1` schema.

```
SELECT diskquota.set_schema_quota('s1', '1MB');
```

4. Insert a large amount of data, enough to exceed the 1MB quota that was set for the schema. Before the `INSERT` command, the `s1` schema is still not on the denylist, so this command should be allowed to start. When the operation exceeds the schema quota, `diskquota` will terminate the query.

```
INSERT INTO a SELECT generate_series(1,10000000);
[hardlimit] schema's disk space quota exceeded
```

5. Remove the quota from the `s1` schema:

```
SELECT diskquota.set_schema_quota('s1', '-1');
```

Setting a Per-Segment Tablespace Quota

This example demonstrates how to configure tablespace and per-segment tablespace quotas. In addition to using the `testdb` database and the `s1` schema that you created in the previous example, this example assumes the following:

- Hard limit enforcement of disk usage is enabled (as in the previous example).
- The WarehousePG cluster has 8 primary segments.
- A tablespace named `tbsp1` has been created in the cluster.

Procedure:

1. Set a disk quota of `1 MB` for the tablespace named `tbsp1` and the schema named `s1`:

```
SELECT diskquota.set_schema_tablespace_quota('s1', 'tbsp1', '1MB');
```

2. Set a per-segment ratio of `2` for the `tbsp1` tablespace:

```
SELECT diskquota.set_per_segment_quota('tbsp1', 2);
```

   With this ratio setting, the average segment quota is `1MB / 8 = 125KB`, and the max per-segment disk usage for the tablespace is `125KB * 2 = 250KB`.

3. Create a new table named `b` and insert some data:

```
CREATE TABLE b(i int);
INSERT INTO b SELECT generate_series(1,100);
```

4. Insert a large amount of data into the table, enough to exceed the 250KB per-segment quota that was set for the tablespace. When the operation exceeds the per-segment tablespace quota, `diskquota` will terminate the query.

```
INSERT INTO b SELECT generate_series(1,10000000);
ERROR:  tablespace: tbsp1, schema: s1 diskquota exceeded per segment quota
```

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7.4.7 fuzzystrmatch

The `fuzzystrmatch` module provides functions to determine similarities and distance between strings based on various algorithms.

The WarehousePG `fuzzystrmatch` module is equivalent to the PostgreSQL `fuzzystrmatch` module. There are no WarehousePG or MPP-specific considerations for the module.

Installing and Registering the Module

The `fuzzystrmatch` module is installed when you install WarehousePG. Before you can use any of the functions defined in the module, you must register the `fuzzystrmatch` extension in each database in which you want to use the functions. Refer to Installing Extensions for more information.

Module Documentation

See fuzzystrmatch in the PostgreSQL documentation for detailed information about the individual functions in this module.

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7.4.8 gp_exttable_fdw

The `gp_exttable_fdw` module is a built-in foreign-data wrapper that converts an external table to a foreign table.

Refer to Understanding the External Table to Foreign Table Mapping for more information about the conversion and runtime implications.

> **Important** Do not register nor directly use the `gp_exttable_fdw` module.

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7.4.9 gp_legacy_string_agg

The `gp_legacy_string_agg` module re-introduces the single-argument `string_agg()` function that was present in WarehousePG 5.

The `gp_legacy_string_agg` module is a WarehousePG extension.

> **Note** Use this module to aid migration from WarehousePG 5 to the native, two-argument `string_agg()` function included in WarehousePG 6.

Installing and Registering the Module

The `gp_legacy_string_agg` module is installed when you install WarehousePG. Before you can use the function defined in the module, you must register the `gp_legacy_string_agg` extension in each database where you want to use the function. Refer to Installing Extensions for more information about registering the module.

Using the Module

The single-argument `string_agg()` function has the following signature:

```
string_agg( text )
```

You can use the function to concatenate non-null input values into a string. For example:

```
SELECT string_agg(a) FROM (VALUES('aaaa'),('bbbb'),('cccc'),(NULL)) g(a);
WARNING:  Deprecated call to string_agg(text), use string_agg(text, text) instead
  string_agg
--------------
 aaaabbbbcccc
(1 row)
```

The function concatenates each string value until it encounters a null value, and then returns the string. The function returns a null value when no rows are selected in the query.

`string_agg()` produces results that depend on the ordering of the input rows. The ordering is unspecified by default; you can control the ordering by specifying an `ORDER BY` clause within the aggregate. For example:

```
CREATE TABLE table1(a int, b text);
INSERT INTO table1 VALUES(4, 'aaaa'),(2, 'bbbb'),(1, 'cccc'), (3, NULL);
SELECT string_agg(b ORDER BY a) FROM table1;
WARNING:  Deprecated call to string_agg(text), use string_agg(text, text) instead
  string_agg
--------------
 ccccbbbb
(1 row)
```

Migrating to the Two-Argument string_agg() Function

WarehousePG 6 includes a native, two-argument, text input `string_agg()` function:

```
string_agg( text, text )
```

The following function invocation is equivalent to the single-argument `string_agg()` function that is provided in this module:

```
string_agg( text, '' )
```

You can use this conversion when you are ready to migrate from this contrib module.

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7.4.10 gp_sparse_vector

The `gp_sparse_vector` module implements a WarehousePG data type and associated functions that use compressed storage of zeros to make vector computations on floating point numbers faster.

The `gp_sparse_vector` module is a WarehousePG extension.

Installing and Registering the Module

The `gp_sparse_vector` module is installed when you install WarehousePG. Before you can use any of the functions defined in the module, you must register the `gp_sparse_vector` extension in each database where you want to use the functions. Refer to Installing Extensions for more information.

Using the gp_sparse_vector Module

When you use arrays of floating point numbers for various calculations, you will often have long runs of zeros. This is common in scientific, retail optimization, and text processing applications. Each floating point number takes 8 bytes of storage in memory and/or disk. Saving those zeros is often impractical. There are also many computations that benefit from skipping over the zeros.

For example, suppose the following array of `double` s is stored as a `float8[]` in WarehousePG:

```
'{0, 33, <40,000 zeros>, 12, 22 }'::float8[]
```

This type of array arises often in text processing, where a dictionary may have 40-100K terms and the number of words in a particular document is stored in a vector. This array would occupy slightly more than 320KB of memory/disk, most of it zeros. Any operation that you perform on this data works on 40,001 fields that are not important.

The WarehousePG built-in `array` datatype utilizes a bitmap for null values, but it is a poor choice for this use case because it is not optimized for `float8[]` or for long runs of zeros instead of nulls, and the bitmap is not run-length-encoding- (RLE) compressed. Even if each zero were stored as a `NULL` in the array, the bitmap for nulls would use 5KB to mark the nulls, which is not nearly as efficient as it could be.

The WarehousePG `gp_sparse_vector` module defines a data type and a simple RLE-based scheme that is biased toward being efficient for zero value bitmaps. This scheme uses only 6 bytes for bitmap storage.

> **Note** The sparse vector data type defined by the `gp_sparse_vector` module is named `svec` . `svec` supports only `float8` vector values.

You can construct an `svec` directly from a float array as follows:

```
SELECT ('{0, 13, 37, 53, 0, 71 }'::float8[])::svec;
```

The `gp_sparse_vector` module supports the vector operators `<` , `>` , `*` , `**` , `/` , `=` , `+` , `sum()` , `vec_count_nonzero()` , and so on. These operators take advantage of the efficient sparse storage format, making computations on `svec` s faster.

The plus (`+`) operator adds each of the terms of two vectors of the same dimension together. For example, if vector `a = {0,1,5}` and vector `b = {4,3,2}` , you would compute the vector addition as follows:

```
SELECT ('{0,1,5}'::float8[]::svec + '{4,3,2}'::float8[]::svec)::float8[];
 float8
---------
 {4,4,7}
```

A vector dot product (`%*%`) between vectors `a` and `b` returns a scalar result of type `float8` . Compute the dot product (`(0*4+1*3+5*2)=13`) as follows:

```
SELECT '{0,1,5}'::float8[]::svec %*% '{4,3,2}'::float8[]::svec;
 ?column?
----------
       13
```

Special vector aggregate functions are also useful. `sum()` is self explanatory. `vec_count_nonzero()` evaluates the count of non-zero terms found in a set of `svec` and returns an `svec` with the counts. For instance, for the set of vectors `{0,1,5},{10,0,3},{0,0,3},{0,1,0}` , the count of non-zero terms would be `{1,2,3}` . Use `vec_count_nonzero()` to compute the count of these vectors:

```
CREATE TABLE listvecs( a svec );

INSERT INTO listvecs VALUES ('{0,1,5}'::float8[]),
    ('{10,0,3}'::float8[]),
    ('{0,0,3}'::float8[]),
    ('{0,1,0}'::float8[]);

SELECT vec_count_nonzero( a )::float8[] FROM listvecs;
 count_vec
-----------
 {1,2,3}
(1 row)
```

Additional Module Documentation

Refer to the `gp_sparse_vector` README s in the WarehousePG github repository for additional information about this module.

Apache MADlib includes an extended implementation of sparse vectors. See the MADlib Documentation for a description of this MADlib module.

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Example

A text classification example that describes a dictionary and some documents follows. You will create WarehousePG tables representing a dictionary and some documents. You then perform document classification using vector arithmetic on word counts and proportions of dictionary words in each document.

Suppose that you have a dictionary composed of words in a text array. Create a table to store the dictionary data and insert some data (words) into the table. For example:

```
CREATE TABLE features (dictionary text[][]) DISTRIBUTED RANDOMLY;
INSERT INTO features
    VALUES ('{am,before,being,bothered,corpus,document,i,in,is,me,never,now,'
            'one,really,second,the,third,this,until}');
```

You have a set of documents, also defined as an array of words. Create a table to represent the documents and insert some data into the table:

```
CREATE TABLE documents(docnum int, document text[]) DISTRIBUTED RANDOMLY;
INSERT INTO documents VALUES
    (1,'{this,is,one,document,in,the,corpus}'),
    (2,'{i,am,the,second,document,in,the,corpus}'),
    (3,'{being,third,never,really,bothered,me,until,now}'),
    (4,'{the,document,before,me,is,the,third,document}');
```

Using the dictionary and document tables, find the dictionary words that are present in each document. To do this, you first prepare a *Sparse Feature Vector*, or SFV, for each document. An SFV is a vector of dimension *N*, where *N* is the number of dictionary words, and each SFV contains a count of each dictionary word in the document.

You can use the `gp_extract_feature_histogram()` function to create an SFV from a document. `gp_extract_feature_histogram()` outputs an `svec` for each document that contains the count of each of the dictionary words in the ordinal positions of the dictionary.

```
SELECT gp_extract_feature_histogram(
    (SELECT dictionary FROM features LIMIT 1), document)::float8[], document
        FROM documents ORDER BY docnum;

     gp_extract_feature_histogram        |                    document
-----------------------------------------+-----------------------------------------------
 {0,0,0,0,1,1,0,1,1,0,0,0,1,0,0,1,0,1,0} | {this,is,one,document,in,the,corpus}
 {1,0,0,0,1,1,1,1,0,0,0,0,0,0,1,2,0,0,0} | {i,am,the,second,document,in,the,corpus}
 {0,0,1,1,0,0,0,0,0,1,1,1,0,1,0,0,1,0,1} | {being,third,never,really,bothered,me,until,now}
 {0,1,0,0,0,2,0,0,1,1,0,0,0,0,0,2,1,0,0} | {the,document,before,me,is,the,third,document}

SELECT * FROM features;
                                          dictionary
-----------------------------------------------------------------------------------------------
 {am,before,being,bothered,corpus,document,i,in,is,me,never,now,one,really,second,the,third,this,until}
```

The SFV of the second document, "i am the second document in the corpus", is `{1,3*0,1,1,1,1,6*0,1,2}`. The word "am" is the first ordinate in the dictionary, and there is `1` instance of it in the SFV. The word "before" has no instances in the document, so its value is `0`; and so on.

`gp_extract_feature_histogram()` is very speed optimized - it is a single routine version of a hash join that processes large numbers of documents into their SFVs in parallel at the highest possible speeds.

For the next part of the processing, generate a sparse vector of the dictionary dimension (19). The vectors that you generate for each document are referred to as the *corpus*.

```
CREATE table corpus (docnum int, feature_vector svec) DISTRIBUTED RANDOMLY;

INSERT INTO corpus
    (SELECT docnum,
        gp_extract_feature_histogram(
            (select dictionary FROM features LIMIT 1), document) from documents);
```

Count the number of times each feature occurs at least once in all documents:

```
SELECT (vec_count_nonzero(feature_vector))::float8[] AS count_in_document FROM corpus;

           count_in_document
-----------------------------------------
 {1,1,1,1,2,3,1,2,2,2,1,1,1,1,1,3,2,1,1}
```

Count all occurrences of each term in all documents:

```
SELECT (sum(feature_vector))::float8[] AS sum_in_document FROM corpus;

            sum_in_document
-----------------------------------------
 {1,1,1,1,2,4,1,2,2,2,1,1,1,1,1,5,2,1,1}
```

The remainder of the classification process is vector math. The count is turned into a weight that reflects *Term Frequency / Inverse Document Frequency* (tf/idf). The calculation for a given term in a given document is:

```
#_times_term_appears_in_this_doc * log( #_docs / #_docs_the_term_appears_in )
```

`#_docs` is the total number of documents (4 in this case). Note that there is one divisor for each dictionary word and its value is the number of times that word appears in the document.

For example, the term "document" in document 1 would have a weight of `1 * log( 4/3 )`. In document 4, the term would have a weight of `2 * log( 4/3 )`. Terms that appear in every document would have weight `0`.

This single vector for the whole corpus is then scalar product multiplied by each document SFV to produce the tf/idf.

Calculate the tf/idf:

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```
SELECT docnum, (feature_vector*logidf)::float8[] AS tf_idf
    FROM (SELECT log(count(feature_vector)/vec_count_nonzero(feature_vector)) AS logidf FROM corpus)
    AS foo, corpus ORDER BY docnum;
 docnum |                                                
```

7.4.11 hstore

The `hstore` module implements a data type for storing sets of (key,value) pairs within a single WarehousePG data field. This can be useful in various scenarios, such as rows with many attributes that are rarely examined, or semi-structured data.

The WarehousePG `hstore` module is equivalent to the PostgreSQL `hstore` module. There are no WarehousePG or MPP-specific considerations for the module.

Installing and Registering the Module

The `hstore` module is installed when you install WarehousePG. Before you can use any of the data types or functions defined in the module, you must register the `hstore` extension in each database in which you want to use the objects. Refer to Installing Extensions for more information.

Module Documentation

See hstore in the PostgreSQL documentation for detailed information about the data types and functions defined in this module.

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7.4.12 ip4r

The `ip4r` module provides IPv4 and IPv6 data types, IPv4 and IPv6 range index data types, and related functions and operators.

The WarehousePG `ip4r` module is equivalent to version 2.4.2 of the `ip4r` module used with PostgreSQL. There are no WarehousePG or MPP-specific considerations for the module.

Installing and Registering the Module

The `ip4r` module is installed when you install WarehousePG. Before you can use any of the data types defined in the module, you must register the `ip4r` extension in each database in which you want to use the types:

```
CREATE EXTENSION ip4r;
```

Refer to Installing Extensions for more information.

Module Documentation

Refer to the ip4r github documentation for detailed information about using the module.

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7.4.13 ltree

The `ltree` module implements a data type named `ltree` that you can use to represent labels of data stored in a hierarchical tree-like structure. The module also provides extensive facilities for searching through label trees.

The WarehousePG `ltree` module is based on the `ltree` module used with PostgreSQL. The WarehousePG version of the module differs as described in theWarehousePG Considerations topic.

Installing and Registering the Module

The `ltree` module is installed when you install WarehousePG. Before you can use any of the data types, functions, or operators defined in the module, you must register the `ltree` extension in each database in which you want to use the objects:

```
CREATE EXTENSION ltree;
```

Refer to Installing Extensions for more information.

Module Documentation

Refer to the ltree PostgreSQL documentation for detailed information about the data types, functions, and operators defined in this module.

WarehousePG Considerations

Because this extension does not provide a hash operator class, columns defined with the data type `ltree` can not be used as the distribution key for a WarehousePG table.

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7.4.14 orafce

The `orafce` module provides Oracle Compatibility SQL functions in WarehousePG. These functions target PostgreSQL but can also be used in WarehousePG.

The WarehousePG `orafce` module is a modified version of the open source Orafce PostgreSQL module extension. The modified `orafce` source files for WarehousePG can be found in the `gpcontrib/orafce` directory in the WarehousePG open source project. The source reflects the Orafce 3.6.1 release and additional commits to 3af70a28f6.

There are some restrictions and limitations when you use the module in WarehousePG.

Installing and Registering the Module

> **Note** Always use the Oracle Compatibility Functions module included with your WarehousePG version. Before upgrading to a new WarehousePG version, uninstall the compatibility functions from each of your databases, and then, when the upgrade is complete, reinstall the compatibility functions from the new WarehousePG release. See the WarehousePG release notes for upgrade prerequisites and procedures.

The `orafce` module is installed when you install WarehousePG. Before you can use any of the functions defined in the module, you must register the `orafce` extension in each database in which you want to use the functions. Refer to Installing Extensions for more information.

WarehousePG Considerations

The following functions are available by default in WarehousePG and do not require installing the Oracle Compatibility Functions:

- sinh()
- tanh()
- cosh()
- decode() (See WarehousePG Implementation Differences for more information.)

WarehousePG Implementation Differences

There are differences in the implementation of the compatibility functions in WarehousePG from the original PostgreSQL `orafce` module extension implementation. Some of the differences are as follows:

- The original `orafce` module implementation performs a decimal round off, the WarehousePG implementation does not:
  - 2.00 becomes 2 in the original module implementation
  - 2.00 remains 2.00 in the WarehousePG implementation
- The provided Oracle compatibility functions handle implicit type conversions differently. For example, using the `decode` function:

  ```
  decode(<expression>, <value>, <return> [,<value>, <return>]...
              [, default])
  ```

  The original `orafce` module implementation automatically converts expression and each value to the data type of the first value before comparing. It automatically converts return to the same data type as the first result.

  The WarehousePG implementation restricts return and `default` to be of the same data type. The expression and value can be different types if the data type of value can be converted into the data type of the expression. This is done implicitly. Otherwise, `decode` fails with an `invalid input syntax` error. For example:

  ```
  SELECT decode('a','M',true,false);
  CASE
  ------
   f
  (1 row)
  SELECT decode(1,'M',true,false);
  ERROR: Invalid input syntax for integer:*"M"
  *LINE 1: SELECT decode(1,'M',true,false);
  ```

- Numbers in `bigint` format are displayed in scientific notation in the original `orafce` module implementation but not in the WarehousePG implementation:
  - 9223372036854775 displays as 9.2234E+15 in the original implementation
  - 9223372036854775 remains 9223372036854775 in the WarehousePG implementation
- The default date and timestamp format in the original `orafce` module implementation is different than the default format in the WarehousePG implementation. If the following code is run:

  ```
  CREATE TABLE TEST(date1 date, time1 timestamp, time2
                    timestamp with time zone);
  INSERT INTO TEST VALUES ('2001-11-11','2001-12-13
                   01:51:15','2001-12-13 01:51:15 -08:00');
  SELECT DECODE(date1, '2001-11-11', '2001-01-01') FROM TEST;
  ```

  The WarehousePG implementation returns the row, but the original implementation returns no rows.

  > **Note** The correct syntax when using the original `orafce` implementation to return the row is:

  ```
  SELECT DECODE(to_char(date1, 'YYYY-MM-DD'), '2001-11-11',
               '2001-01-01') FROM TEST
  ```

- The functions in the Oracle Compatibility Functions `dbms_alert` package are not implemented for WarehousePG.
- The `decode()` function is removed from the WarehousePG Oracle Compatibility Functions. The WarehousePG parser internally converts a `decode()` function call to a `CASE` statement.

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Using orafce

Some Oracle Compatibility Functions reside in the `oracle` schema. To access them, set the search path for the database to include the `oracle` schema name. For example, this command sets the default search path for a database to include the `oracle` schema:

```
ALTER DATABASE <db_name> SET <search_path> = "$user", public, oracle;
```

Note the following differences when using the Oracle Compatibility Functions with PostgreSQL vs. using them with WarehousePG:

- If you use validation scripts, the output may not be exactly the same as with the original `orafce` module implementation.
- The functions in the Oracle Compatibility Functions `dbms_pipe` package run only on the WarehousePG coordinator host.
- The upgrade scripts in the Orafce project do not work with WarehousePG.

Additional Module Documentation

Refer to the README and WarehousePG orafce documentation in the WarehousePG github repository for detailed information about the individual functions and supporting objects provided in this module.

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7.4.15 pageinspect

The `pageinspect` module provides functions for low level inspection of the contents of database pages. `pageinspect` is available only to WarehousePG superusers.

The WarehousePG `pageinspect` module is based on the PostgreSQL `pageinspect` module. The WarehousePG version of the module differs as described in the WarehousePG Considerations topic.

Installing and Registering the Module

The `pageinspect` module is installed when you install WarehousePG. Before you can use any of the functions defined in the module, you must register the `pageinspect` extension in each database in which you want to use the functions:

```
CREATE EXTENSION pageinspect;
```

Refer to Installing Extensions for more information.

Upgrading the Module

If you are currently using `pageinspect` in your WarehousePG installation and you want to access newly-released module functionality, you must update the `pageinspect` extension in every database in which it is currently registered:

```
ALTER EXTENSION pageinspect UPDATE;
```

Module Documentation

See pageinspect in the PostgreSQL documentation for detailed information about the majority of functions in this module.

The next topic includes documentation for WarehousePG-added `pageinspect` functions.

WarehousePG Considerations

When using this module with WarehousePG, consider the following:

- The WarehousePG version of the `pageinspect` does not allow inspection of pages belonging to append-optimized or external relations.
- For `pageinspect` functions that read data from a database, the function reads data only from the segment instance where the function is run. For example, the `get_raw_page()` function returns a `block number out of range` error when you try to read data from a user-defined table on the WarehousePG coordinator because there is no data in the table on the coordinator segment. The function will read data from a system catalog table on the coordinator segment.

WarehousePG-Added Functions

In addition to the functions specified in the PostgreSQL documentation, WarehousePG provides these additional `pageinspect` functions for inspecting bitmap index pages:

Function Name	Description
bm_metap(relname text) returns record	Returns information about a bitmap index's meta page.
bm_bitmap_page_header(relname text, blkno int) returns record	Returns the header information for a bitmap page; this corresponds to the opaque section from the page header.
bm_lov_page_items(relname text, blkno int) returns setof record	Returns the list of value (LOV) items present in a bitmap LOV page.
bm_bitmap_page_items(relname text, blkno int) returns setof record	Returns the content words and their compression statuses for a bitmap page.
bm_bitmap_page_items(page bytea) returns setof record	Returns the content words and their compression statuses for a page image obtained by `get_raw_page()`.

Examples

WarehousePG-added `pageinspect` function usage examples follow.

Obtain information about the meta page of the bitmap index named `i1`:

```
testdb=# SELECT * FROM bm_metap('i1');
   magic    | version | auxrelid | auxindexrelid | lovlastblknum
------------+---------+----------+---------------+---------------
 1112101965 |       2 |   169980 |        169982 |             1
(1 row)
```

Display the header information for the second block of the bitmap index named `i1`:

```
testdb=# SELECT * FROM bm_bitmap_page_header('i1', 2);
 num_words | next_blkno | last_tid
-----------+------------+----------
 3         | 4294967295 | 65536
(1 row)
```

Display the LOV items located in the first block of the bitmap index named `i1`:

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```
testdb=# SELECT * FROM bm_lov_page_items('i1', 1) ORDER BY itemoffset;
 itemoffset | lov_head_blkno | lov_tail_blkno | last_complete_word      | last_word               | last_tid | last_setbit_tid | is_last_complete_word_fill |
is_last_word_fill
------------+----------------+----------------+-------------------------+-------------------------+----------+-----------------+----------------------------+-------
-------
 1          | 4294967295     | 4294967295     | ff ff ff ff ff ff ff ff | 00 00 00 00 00 00 00 00 | 0        | 0               | f                          | f
 2          | 2              | 2              | 80 00 00 00 00 00 00 01 | 00 00 00 00 07 ff ff ff | 65600    | 65627           | t                          | f
 3          | 3              | 3              | 80 00 00 00 00 00 00 02 | 00 3f ff ff ff ff ff ff | 131200   | 131254          | t                          | f
(3 rows)
```

Return the content words located in the second block of the bitmap index named `i1`:

```
testdb=# SELECT * FROM bm_bitmap_page_items('i1', 2) ORDER BY word_num;
 word_num | compressed | content_word
----------+------------+-------------------------
 0        | t          | 80 00 00 00 00 00 00 0e
 1        | f          | 00 00 00 00 00 00 1f ff
 2        | t          | 00 00 00 00 00 00 03 f1
(3 rows)
```

Alternatively, return the content words located in the heap page image of the same bitmap index and block:

```
testdb=# SELECT * FROM bm_bitmap_page_items(get_raw_page('i1', 2)) ORDER BY word_num;
 word_num | compressed | content_word
----------+------------+-------------------------
 0        | t          | 80 00 00 00 00 00 00 0e
 1        | f          | 00 00 00 00 00 00 1f ff
 2        | t          | 00 00 00 00 00 00 03 f1
(3 rows)
```

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7.4.16 pg_buffercache

The `pg_buffercache` module provides five views for obtaining cluster-wide shared buffer metrics:

- `gp_buffercache`
- `gp_buffercache_summary`
- `gp_buffercache_usage_counts`
- `gp_buffercache_summary_aggregated`
- `gp_buffercache_usage_counts_aggregated`

The `gp_buffercache` view is a cluster-wide view that displays the `pg_buffercache` information from the coordinator and every primary segment for each buffer in the shared cache.

The `gp_buffercache_summary` view is a cluster-wide view that displays the `pg_buffercache_summary` information from the coordinator and each primary segment, summarized as one row per segment. Similar and more detailed information is provided by `gp_buffercache`, but `gp_buffercache_summary` is significantly better performance-wise.

The `gp_buffercache_usage_counts` view is a cluster-wide view that displays the `pg_puffercache_usage_counts` information from the coordinator and each primary segment returning summarized states of all shared buffers, aggregated over the possible usage count values. Similar and more detailed information is provided by `gp_buffercache`, but `gp_buffercache_usage_counts` is significantly better performance-wise.

The `gp_buffercache_summary_aggregated` view returns a single row with the aggregated output of `gp_buffercache_summary`.

The `gp_buffercache_usage_counts_aggregated` view returns a single row with the aggregated output of `gp_buffercache_usage_counts`.

Installing and Registering the Module

The `pg_buffercache` module is installed when you install WarehousePG. Before you can use any of the functions defined in the module, you must register the `pg_buffercache` extension in each database in which you want to use the functions:

```
CREATE EXTENSION pg_buffercache;
```

Refer to Installing Extensions for more information.

Module Documentation

See pg_buffercache in the PostgreSQL documentation for detailed information about the individual functions in this module.

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7.4.17 pg_cron

The `pg_cron` module is a cron-based job scheduler that runs inside the database.

Installing and Registering the Module

The `pg_cron` module is installed when you install WarehousePG. Before you can use it, you must perform the following steps:

You can only install the `pg_cron` module in one database per WarehousePG cluster. First, set the database where you want `pg_cron` to create its metadata tables, by default it uses the `postgres` database. In order to change it, run the following command and restart WarehousePG:

```
gpconfig -c cron.database_name -v 'db_name' --skipvalidation
```

Enable the extension as a preloaded library. First, check if there are any preloaded shared libraries by running the `gpconfig` command. The following example shows that the `auto_explain` libraries are already enabled for the cluster:

```
gpconfig -s shared_preload_libraries
Values on all segments are consistent
GUC              : shared_preload_libraries
Coordinator value: auto_explain
Segment     value: auto_explain
```

Use the output of the above command to enable the `pg_cron` module, along any other shared libraries, and restart WarehousePG:

```
gpconfig -c shared_preload_libraries -v 'auto_explain,pg_cron'
gpstop -ar
```

Register the `pg_cron` extension in the desired database. You can only install `pg_cron` in one database per cluster.

```
CREATE EXTENSION pg_cron;
```

Optionally, grant usage to specific users:

```
GRANT USAGE ON SCHEMA cron TO user1;
```

Refer to Installing Extensions for more information.

Upgrading the Module

The `pg_cron` module is installed when you install or upgrade WarehousePG. A previous version of the extension will continue to work in existing databases after you upgrade WarehousePG. To upgrade to the most recent version of the extension, you must:

```
ALTER EXTENSION pg_cron UPDATE TO '1.6.2';
```

Using the pg_cron Module

Use the user-defined functions (UDFs) under the `cron` schema to schedule cron jobs in your default database. For example, configure a job that deletes old database data every Saturday at 3:30am (GMT):

```
SELECT cron.schedule('30 3 * * 6', $$DELETE FROM events WHERE event_time < now() - interval '1 week'$$);
 schedule
----------
       42
```

Optionally, you may update the database column for the job that you just created so that it runs in another database within your WarehousePG cluster. Run the following command as a user with the superuser role:

```
UPDATE cron.job SET database = 'database1' WHERE jobid = 106;
SELECT cron.reload_job();
```

You may use the UDF `cron.schedule_in_database()` to schedule jobs in multiple databases. Below are the function arguments:

```
cron.schedule_in_database(job_name text,
schedule text,
command text,
database text,
username text default null,
active boolean default 'true')
```

For example, run `VACUUM` every Sunday at 4:00am (GMT) in a database other than the one `pg_cron` is installed on:

```
SELECT cron.schedule_in_database('weekly-vacuum', '0 4 * * 0', 'VACUUM', 'some_other_database');
 schedule
----------
       44
```

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> **Important** Since the `TRIGGER` statement is not supported in WarehousePG, if a user runs an `UPDATE` or `INSERT` statement, or manually deletes any of the cron jobs instead of using the UDFs in the `cron` schema, you must run the following UDF to update the `pg_cron` cache:
>
> ```
> SELECT cron.reload_job();
> ```

> **Note** The server configuration parameter `cron.use_background_workers` is not supported on WarehousePG 6.

Module Documentation

Refer to the pg_cron github documentation for more information about using the module.

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7.4.18 pg_stat_statements

`pg_stat_statements` is a core PostgreSQL module that provides a means to track planning and execution statistics of all SQL statements executed by the server.

In WarehousePG (WHPG) distributed architecture, query execution is parallelized across the coordinator and multiple segments. The WHPG implementation of this module provides cluster-wide visibility, collecting performance metrics from every segment node. This allows administrators to analyze buffer usage, I/O operations, and execution patterns across the entire distributed cluster rather than just the coordinator.

By extending standard functionality into the parallel execution layer, `pg_stat_statements` enables:

- Comprehensive distributed tracking across all query executors.
- Unified visibility through specialized system views for both raw and aggregated data.
- Centralized management for resetting performance metrics across the entire cluster simultaneously.

Loading the module

`pg_stat_statements` is shipped with WarehousePG 7.4 and later. You must load the extension as a shared library before you can use it within your databases.

1. Load the extension as a shared library before you can use it within your databases. Check for existing shared libraries:

   ```
   gpconfig -s
   shared_preload_libraries
   ```

2. Use the output of the previous command to enable `pg_stat_statements1, along any other shared libraries, and restart WHPG:

   ```
   gpconfig -c shared_preload_libraries -v '<other_libraries>,
   pg_stat_statements'
   gpstop -ar
   ```

3. Create the extension in your database:

   ```
   CREATE EXTENSION
   pg_stat_statements;
   ```

Analyzing performance with distributed views

The statistics gathered by the module are made available via two specialized views:

whpg_stat_statements

This view displays raw statistics from the coordinator and all segments in a single table.

```
SELECT * FROM
whpg_stat_statements;
```

Column	Type	Description
`gp_segment_id`	`integer`	Segment identifier: `-1` for the coordinator, `0...N-1` for segments.
`userid`	`oid`	OID of the user who executed the statement.
`dbid`	`oid`	OID of the database in which the statement was executed.
`queryid`	`bigint`	Internal hash code computed from the statement's parse tree.
`query`	`text`	Normalized representative query text.
`plans`	`bigint`	Number of times the statement was planned.
`total_plan_time`	`double precision`	Total time spent planning the statement (milliseconds).
`calls`	`bigint`	Number of times the statement was executed.
`total_exec_time`	`double precision`	Total time spent executing the statement (milliseconds).
`rows`	`bigint`	Total number of rows retrieved or affected by the statement.
`shared_blks_hit`	`bigint`	Total number of shared block cache hits.
`shared_blks_read`	`bigint`	Total number of shared blocks read from disk.
`shared_blks_dirtied`	`bigint`	Total number of shared blocks dirtied.
`shared_blks_written`	`bigint`	Total number of shared blocks written to disk.
`local_blks_hit`	`bigint`	Total number of local block cache hits.
`local_blks_read`	`bigint`	Total number of local blocks read from disk.
`temp_blks_read`	`bigint`	Total number of temporary blocks read from disk.
`temp_blks_written`	`bigint`	Total number of temporary blocks written to disk.
`blk_read_time`	`double precision`	Total time spent reading blocks (if `track_io_timing` is enabled).
`blk_write_time`	`double precision`	Total time spent writing blocks (if `track_io_timing` is enabled).
`wal_records`	`bigint`	Total number of WAL records generated by the statement.
`wal_bytes`	`numeric`	Total number of WAL bytes generated by the statement.

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whpg_stat_statements_aggregated

This view provides a unified summary of total resource consumption per query across the entire cluster.

```
SELECT * FROM whpg_stat_statements_aggregated;
```

Column	Type	Description
`userid`	`oid`	OID of the user.
`dbid`	`oid`	OID of the database.
`queryid`	`bigint`	Internal hash code.
`query`	`text`	Normalized representative query text.
`calls`	`bigint`	Total number of executions.
`total_time`	`double precision`	Total time spent executing.
`min_time`	`double precision`	Minimum time spent executing.
`max_time`	`double precision`	Maximum time spent executing.
`mean_time`	`double precision`	Mean time spent executing.
`stddev_time`	`double precision`	Population standard deviation of execution time.
`rows`	`bigint`	Total rows retrieved/affected.
`shared_blks_hit`	`bigint`	Total shared block cache hits.
`shared_blks_read`	`bigint`	Total shared blocks read from disk.
`shared_blks_dirtied`	`bigint`	Total shared blocks dirtied.
`shared_blks_written`	`bigint`	Total shared blocks written to disk.
`local_blks_hit`	`bigint`	Total local block cache hits.
`local_blks_read`	`bigint`	Total local blocks read from disk.
`local_blks_dirtied`	`bigint`	Total local blocks dirtied.
`local_blks_written`	`bigint`	Total local blocks written to disk.
`temp_blks_read`	`bigint`	Total temporary blocks read from disk.
`temp_blks_written`	`bigint`	Total temporary blocks written to disk.
`blk_read_time`	`double precision`	Total block read time.
`blk_write_time`	`double precision`	Total block write time.

To provide a consolidated view of cluster performance, the metrics in this view are processed as follows:

- Buffer and I/O statistics (`shared_blks_*` , `local_blks_*` , `temp_blks_*` , `blk_*_time`) are summed across all nodes to show total cluster effort.
- Timing statistics (`total_time` , `min_time` , `max_time` , `mean_time`) reflect the values recorded at the coordinator level, representing the actual duration experienced by the user.

Managing statistics globally

The `pg_stat_statements` module includes functions to manage and clear gathered performance data.

whpg_stat_statements_reset

Resets all collected statistics on the coordinator and all segments simultaneously.

```
-- Global reset for all users and
databases
SELECT
whpg_stat_statements_reset();

-- Targeted reset for specific user, database, or
query
SELECT whpg_stat_statements_reset(userid, dbid,
queryid);
```

Parameter	Type	Description
`p_userid`	`Oid`	Reset entries for a specific user (use `0` for all users).
`p_dbid`	`Oid`	Reset entries for a specific database (use `0` for all databases).
`p_queryid`	`bigint`	Reset a specific query signature (use `0` for all queries).

> **Note**
>
> This function requires superuser privileges.

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Examples

View per-segment buffer usage

Check if specific segments are performing significantly more physical reads than others, which often indicates poor data distribution.

```
SELECT

gp_segment_id,
    query,
    shared_blks_read,

shared_blks_hit,
    blk_read_time
FROM whpg_stat_statements
WHERE query LIKE '%my_table%'
ORDER BY
gp_segment_id;
```

Get aggregated statistics

Identify queries consuming the most total I/O time summed across the entire cluster.

```
SELECT
    query,

calls,
    rows,

shared_blks_hit,
    blk_read_time + blk_write_time AS
total_io_time_ms
FROM
whpg_stat_statements_aggregated
ORDER BY total_io_time_ms
DESC
LIMIT 10;
```

Reset statistics before benchmarking

To ensure accurate results for a new workload, reset all cluster statistics first.

```
-- 1. Clear cluster-wide
history
SELECT
whpg_stat_statements_reset();

-- 2. Run
workload
-- [Queries]

-- 3. Analyze aggregated cluster costs
SELECT * FROM whpg_stat_statements_aggregated;
```

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7.4.19 pg_trgm

The `pg_trgm` module provides functions and operators for determining the similarity of alphanumeric text based on trigram matching. The module also provides index operator classes that support fast searching for similar strings.

The WarehousePG `pg_trgm` module is equivalent to the PostgreSQL `pg_trgm` module. There are no WarehousePG or MPP-specific considerations for the module.

Installing and Registering the Module

The `pg_trgm` module is installed when you install WarehousePG. Before you can use any of the functions defined in the module, you must register the `pg_trgm` extension in each database in which you want to use the functions:

```
CREATE EXTENSION pg_trgm;
```

Refer to Installing Extensions for more information.

Module Documentation

See pg_trgm in the PostgreSQL documentation for detailed information about the individual functions in this module.

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7.4.20 pgcrypto

WarehousePG is installed with an optional module of encryption/decryption functions called `pgcrypto`. The `pgcrypto` functions allow database administrators to store certain columns of data in encrypted form. This adds an extra layer of protection for sensitive data, as data stored in WarehousePG in encrypted form cannot be read by anyone who does not have the encryption key, nor can it be read directly from the disks.

> **Note** The `pgcrypto` functions run inside the database server, which means that all the data and passwords move between `pgcrypto` and the client application in clear-text. For optimal security, consider also using SSL connections between the client and the WarehousePG coordinator server.

Installing and Registering the Module

The `pgcrypto` module is installed when you install WarehousePG. Before you can use any of the functions defined in the module, you must register the `pgcrypto` extension in each database in which you want to use the functions. Refer to Installing Extensions for more information.

Configuring FIPS Encryption

Starting with WarehousePG 6.22, the `pgcrypto` extension provides a module-specific configuration parameter, `pgcrypto.fips`. This parameter configures WarehousePG support for a limited set of FIPS encryption functionality (*Federal Information Processing Standard* (FIPS) 140-2). For information about FIPS, see https://www.nist.gov/itl/popular-links/federal-information-processing-standards-fips. The default setting is `off`, FIPS encryption is not enabled.

Before enabling this parameter, ensure that FIPS is enabled on all WarehousePG cluster hosts.

When this parameter is enabled, these changes occur:

- FIPS mode is initialized in the OpenSSL library
- The functions `digest()` and `hmac()` allow only the SHA encryption algorithm (MD5 is not allowed)
- The functions for the crypt and gen_salt algorithms are disabled
- PGP encryption and decryption functions support only AES and 3DES encryption algorithms (other algorithms such as blowfish are not allowed)
- RAW encryption and decryption functions support only AES and 3DES (other algorithms such as blowfish are not allowed)

To enable `pgcrypto.fips`

1. Enable the `pgcrypto` functions as an extension if it is not enabled. See Installing Extensions. This example `psql` command creates the `pgcrypto` extension in the database `testdb`.

   ```
   psql -d testdb -c 'CREATE EXTENSION pgcrypto'
   ```

2. Configure the WarehousePG server configuration parameter `shared_preload_libraries` to load the `pgcrypto` library. This example uses the `gpconfig` utility to update the parameter in the WarehousePG `postgresql.conf` files.

   ```
   gpconfig -c shared_preload_libraries -v '$libdir/pgcrypto'
   ```

   This command displays the value of `shared_preload_libraries`.

   ```
   gpconfig -s shared_preload_libraries
   ```

3. Restart the WarehousePG cluster.

   ```
   gpstop -ra
   ```

4. Set the `pgcrypto.fips` server configuration parameter to `on` for each database that uses FIPS encryption. For example, these commands set the parameter to `on` for the database `testdb`.

   ```
   psql -d postgres
   ```

   ```
   ALTER DATABASE testdb SET pgcrypto.fips TO on;
   ```

   > **Important** You must use the `ALTER DATABASE` command to set the parameter. You cannot use the `SET` command that updates the parameter for a session, or use the `gpconfig` utility that updates `postgresql.conf` files.

5. After setting the parameter, reconnect to the database to enable encryption support for a session. This example uses the `psql` meta command `\c` to connect to the `testdb` database.

   ```
   \c testdb
   ```

To disable `pgcrypto.fips`

1. If the database does not use `pgcrypto` functions, disable the `pgcrypto` extension. This example `psql` command drops the `pgcrypto` extension in the database `testdb`.

   ```
   psql -d testdb -c 'DROP EXTENSION pgcrypto'
   ```

2. Remove `\$libdir/pgcrypto` from the `shared_preload_libraries` parameter, and restart WarehousePG. This `gpconfig` command displays the value of the parameter from the WarehousePG `postgresql.conf` files.

   ```
   gpconfig -s shared_preload_libraries
   ```

   Use the `gpconfig` utility with the `-c` and `-v` options to change the value of the parameter. Use the `-r` option to remove the parameter.

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3. Restart the WarehousePG cluster.

```
gpstop -ra
```

Additional Module Documentation

Refer to pgcrypto in the PostgreSQL documentation for more information about the individual functions in this module.

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7.4.21 postgresml

PostgresML is a machine learning extension for PostgreSQL that enables you to perform training and inference on text and tabular data using SQL queries. With PostgresML, you can seamlessly integrate machine learning models into your WarehousePG and harness the power of cutting-edge algorithms to process data efficiently.

The `postgresml` module provides PostgresML functions for using tens of thousands of pre-trained open source AI/machine learning models in WarehousePG. The models are provided by theHugging Face AI data science platform.

Before Registering the `postgresml` Module

Before registering the `postgresml` module, you must install the Data Science bundle for Python3.11, add the `pgml` library to the set of libraries the WarehousePG server loads at startup, and set the Python virtual environment:

1. Install the Data Science bundle for Python 3.11.
2. Add the `postgresml` library to preload when the WarehousePG server starts, using the `shared_preload_libraries` server configuration parameter and then restart the cluster.

   For example:

   ```
   gpconfig -c shared_preload_libraries -v 'xxx, pgml'
   ```

   where xxx represents any existing preloaded libraries.
3. Set the Python virtual environment.

   At the session level:

   ```
   SET pgml.venv='$GPHOME/ext/DataSciencePython3.11';
   ```

   To last beyond a session:

   ```
   gpconfig -c pgml.venv -v '$GPHOME/ext/DataSciencePython3.11'
   gpstop -u
   ```

> **Note** If this yields the error message, `[CRITICAL]:-not a valid GUC: pgml.venv` it means you failed to run Step 2, including restarting the cluster, beforehand.

Proceed to the next section to register the `postgresml` module.

Registering the Module

The `postgresml` module is installed when you install WarehousePG. Before you can use any of the data types, functions, or operators defined in the module, you must register the `postgresml` extension in each database in which you want to use the objects:

```
CREATE EXTENSION pgml;
```

Refer to Installing Extensions for more information.

Upgrading the Module

The `PostgresML` module is installed when you install or upgrade WarehousePG. A previous version of the extension will continue to work in existing databases after you upgrade WarehousePG. To upgrade to the most recent version of the extension, you must:

```
ALTER EXTENSION pgml UPDATE TO '2.7.13+greenplum.1.0.0';
```

in **every** database in which you registered/use the extension.

User-Defined Functions

The `postgresml` extension currently supports just a subset of all of the user-defined functions provided by PostgresML. They are these three:

- `pgml.load_dataset()` : Loads a dataset into tables in WarehousePG using the `INSERT` SQL command. Read more about loading data here.
- `pgml.embed()` - Generates an embedding for the dataset. Read more about PostgresML embeddings here.
- `pgml.transform()` : Applies a pre-trained transformer to process data. Read more about PostgresML pre-trained models here.
- `pgml.train()` : Handles different training tasks which are configurable with the function parameters. Read more about supervised learning here.
- `pgml.predict()` : Provides online predictions using the best, automatically deployed model for a project. Read more about supervised learning here.

additional PostgresML functions may be available in the future based on demand

pgml.load_dataset()

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Syntax

```
pgml.load_dataset(
    source TEXT,
    subset TEXT,
    limit bigint,
    kwargs JSONB
)
```

where:

`source` is the name of the data source. `subset` is a subset of the data source. The default is `NULL`. `limit` is a user-defined limit on the number of imported rows. The default is `NULL`. `kwargs` is a a JSONB object containing optional arguments. The default is an empty object (`{}`).

pgml.embed()

Syntax

```
pgml.embed(
    transformer TEXT,
    inputs TEXT or TEXT[],
    kwargs JSONB
)
```

where:

- `transformer` is the huggingface sentence-transformer name.
- `inputs` are the text(s) to embed. It can be a single text string or an array of texts.
- `kwargs` is a JSONB object containing optional arguments.

pgml.transform()

Syntax

```
pgml.transform(
    task TEXT or JSONB,
    call JSONB,
    inputs TEXT[] or BYTEA[]
)
```

where:

- `task` is the task name passed as either a simple text string or, for a more complex task setup, a JSONB object containing a full pipeline and initializer arguments.
- `call` is a JSONB object containing call arguments passed alongside the `inputs` values.
- `inputs` is a `TEXT[]` or `BYTEA[]` array containing inputs for inference.

> **Note** You must explicitly specify a model when calling `pgml.transform()`; default models are not yet supported.

pgml.train()

Syntax

```
pgml.train(
    project_name TEXT,
    task TEXT DEFAULT NULL,
    relation_name TEXT DEFAULT NULL,
    y_column_name TEXT DEFAULT NULL,
    algorithm TEXT DEFAULT 'linear',
    hyperparams JSONB DEFAULT '{}'::JSONB,
    search TEXT DEFAULT NULL,
    search_params JSONB DEFAULT '{}'::JSONB,
    search_args JSONB DEFAULT '{}'::JSONB,
    test_size REAL DEFAULT 0.25,
    test_sampling TEXT DEFAULT 'random',
    preprocess JSONB DEFAULT '{}'::JSONB
)
```

where

- `project_name` is an easily recognizable identifier to organize your work.
- `task` is the objective of the experiment: `regression`, `classification`, or `cluster`.
- `relation_name` is the Postgres table or view where the training data is stored or defined.
- `y_column_name` is the name of the label column in the training table.
- `algorithm` is the algorithm to train on the dataset, the available algorithms are `regression`, `classification`, and `clustering`.
- `hyperparams` are the hyperparameters to pass to the algorithm for training, JSON formatted.
- `search` indicates, if set, whether or not PostgresML performs a hyperparameter search to find the best hyperparameters for the algorithm.
- `search_params` are the search parameters used in the `hyperparameter` search, using the scikit-learn notation, JSON formatted.
- `search_args` are the configuration parameters for the `search`, JSON formatted. Currently only `n_iter` is supported for `random` search.
- `test_size` is the fraction of the dataset to use for the test set and algorithm validation.
- `test_sampling` is the algorithm used to fetch test data from the dataset: `random`, `first`, or `last`.
- `preprocess` are the preprocessing steps to impute NULLS, encode categoricals and scale inputs.

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For more information about the available algorithms, hyperparameter search, and data pre-processing, visit the officialPostgresML Documentation.

pgml.predict()

Syntax

```
select pgml.predict (
    project_name TEXT,
    features REAL[]
)
```

where

- `project_name` is the project name used to train models in pgml.train().
- `features` is an aggregate of feature vectors used to predict novel data points

Examples

The following example:

1. Downloads a dataset from the internet and creates a table to contain the data.
2. Generates an embedding for the text.
3. Downloads and runs pre-trained models.

```
# Download the dataset from the internet and create table for it

SELECT pgml.load_dataset('tweet_eval', 'sentiment');

# Generate an embedding for the text

SELECT pgml.embed('distilbert-base-uncased', 'Star Wars christmas special is on Disney')::vector AS embedding;
-----------------------------------------------------------------------------------------------

SELECT text, pgml.embed('distilbert-base-uncased', text)

FROM pgml.tweet_eval limit 5;

-----------------------------------------------------------------------------------------------

CREATE TABLE tweet_embeddings AS

SELECT text, pgml.embed('distilbert-base-uncased', text) AS embedding

FROM pgml.tweet_eval limit 5;

# Download and run pre-trained models

SELECT pgml.transform(
    'translation_en_to_fr',
    inputs => ARRAY[
        'Welcome to the future!',
        'Where have you been all this time?'
    ]
) AS french;
```

The following example:

1. Obtains training data.
2. Trains a model.
3. Performs a prediction.

```
# Obtain training data from a dataset

SELECT * FROM pgml.load_dataset('digits');
SELECT target, image
FROM pgml.digits LIMIT 5;

# Train a model using an algorithm using the default linear algorithm

SELECT * FROM pgml.train(
'Handwritten Digit Image Classifier',
'classification',
'pgml.digits',
'target'
);

# Predict

SELECT
target,
pgml.predict('Handwritten Digit Image Classifier', image) AS prediction
FROM pgml.digits
LIMIT 10;
```

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7.4.22 postgres_fdw

The `postgres_fdw` module is a foreign-data wrapper (FDW) that you can use to access data stored in a remote PostgreSQL or WarehousePG.

The WarehousePG `postgres_fdw` module is a modified version of the PostgreSQL `postgres_fdw` module. The module behaves as described in the PostgreSQL postgres_fdw documentation when you use it to access a single remote PostgreSQL database. The WarehousePG `postgres_fdw` module also includes enhancements that allow you to access multiple remote PostgreSQL servers from a single foreign table.

> **Note** There are some restrictions and limitations when you use this foreign-data wrapper module, described below.

Installing and Registering the Module

The `postgres_fdw` module is installed when you install WarehousePG. Before you can use the foreign-data wrapper, you must register the `postgres_fdw` extension in each database in which you want to use the foreign-data wrapper. Refer to Installing Extensions for more information.

Using postgres_fdw to Access Multiple Remote PostgreSQL Servers

Before you create a foreign table using the `postgres_fdw` foreign-data wrapper, you must configure a server with the CREATE SERVER command. You can use a `postgres_fdw` foreign table to access data that is distributed across multiple remote PostgreSQL servers when you set certain WarehousePG and `postgres_fdw` -specific options on the `CREATE SERVER` command:

Option Name	Description	Value
mpp_execute	WarehousePG option that identifies the host(s) from which `postgres_fdw` reads or writes data.	Set to `'all segments'`, which, when specified for `postgres_fdw`, translates to all remote PostgreSQL servers specified in `multi_hosts`.
num_segments[1]	WarehousePG option that identifies the number of query executors that WarehousePG spawns on the source WarehousePG cluster.	Set to the number of remote PostgreSQL servers. If this option is not set, defaults to the number of segments in the local WarehousePG cluster.
multi_hosts	Space-separated list of remote PostgreSQL server host names.	You must specify exactly `num_segments` number of hosts in the list.
multi_ports	Space-separated list of port numbers for the PostgreSQL servers.	You must specify exactly one port number for each host specified in `multi_hosts`, in order.

[1] The WarehousePG query optimizer (GPORCA) can plan and optimize queries only when `num_segments` is equal to the number of segments in the local WarehousePG cluster. When `num_segments` is any other value, a query always falls back to the Postgres-based planner.

Setting these options instructs `postgres_fdw` to treat a foreign table that you create that specifes this `SERVER` as a *distributed* foreign table. That is, a foreign table whose underlying data is stored on multiple remote PostgreSQL servers. `postgres_fdw` directs a query on such a foreign table to each PostgreSQL server specified in `multi_hosts`.

An example `CREATE SERVER` command that configures access to PostgreSQL servers running on `pghost1` and `pghost2` follows:

```
CREATE SERVER
dist_pgserver
  FOREIGN DATA WRAPPER postgres_fdw
OPTIONS (multi_hosts 'pghost1 pghost2', multi_ports '5432 5555', num_segments '2', mpp_execute 'all
segments');
```

About Aggregate Pushdown Support

`postgres_fdw` supports partial aggregate pushdown for a *distributed* query under the following conditions:

- The aggregate contains no `DISTINCT` or `ORDER BY` clauses.
- The aggregate does not contain `HAVING` clause.
- The aggregate function is not `array_agg()`.
- The query contains no `LIMIT` or `JOIN` clauses.

> **Note** `postgres_fdw` does not support partial aggregate pushdown when the WarehousePG query optimizer (GPORCA) is enabled for a query.

About Limit Pushdown Support

`postgres_fdw` supports limit pushdown for a *distributed* query under the following conditions:

- The query contains no `OFFSET` clause.
- The query contains no aggregates.

Distributed postgres_fdw Limitations

When you use the foreign-data wrapper to access multiple remote PostgreSQL servers, WarehousePG `postgres_fdw` has the following limitations:

- You must set the `gp_enable_minmax_optimization` server configuration parameter to `off` to enable partial aggregate pushdown.
- `INSERT`, `UPDATE`, and `DELETE` operations on distributed foreign tables are not supported.
- `IMPORT FOREIGN SCHEMA` is not supported.

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WarehousePG Limitations

When you use the foreign-data wrapper to access WarehousePG, `postgres_fdw` has the following limitations:

- The `ctid` is not guaranteed to uniquely identify the physical location of a row within its table. For example, the following statements may return incorrect results when the foreign table references a WarehousePG table:

```
INSERT INTO rem1(f2) VALUES ('test') RETURNING ctid;
SELECT * FROM ft1, t1 WHERE t1.ctid = '(0,2)';
```

- `postgres_fdw` does not support local or remote triggers when you use it to access a foreign table that references a WarehousePG table.
- `UPDATE` or `DELETE` operations on a foreign table that references a WarehousePG table are not guaranteed to work correctly.

Additional Module Documentation

For more information about using foreign tables in WarehousePG, seeAccessing External Data with Foreign Tables.

For detailed information about this module, refer to the postgres_fdw PostgreSQL documentation.

The `postgres_fdw` foreign-data wrapper is included in the WarehousePG open source github repository. You can view the source code for the module which is located in the `contrib/` directory.

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7.4.23 postgresql-hll

The `postgresql-hll` module provides native HyperLogLog data types and relation functions, operators, and aggregates.

The WarehousePG `postgresql-hll` module is equivalent to version 2.16 of the `postgresql-hll` used with PostgreSQL. There are no WarehousePG or MPP-specific considerations for the module.

Installing and Registering the Module

The `postgresql-hll` module is installed when you install WarehousePG. Before you can use the data types defined in the module, you must register the `hll` extension in each database in which you want to use the types:

```
CREATE EXTENSION hll;
```

Refer to Installing Extensions for more information.

Module Documentation

Refer to the postgresql-hll github documentation for detailed information about using the module.

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7.4.24 sslinfo

The `sslinfo` module provides information about the SSL certificate that the current client provided when connecting to WarehousePG. Most functions in this module return NULL if the current connection does not use SSL.

The WarehousePG `sslinfo` module is equivalent to the PostgreSQL `sslinfo` module. There are no WarehousePG or MPP-specific considerations for the module.

Installing and Registering the Module

The `sslinfo` module is installed when you install WarehousePG. Before you can use any of the functions defined in the module, you must register the `sslinfo` extension in each database in which you want to use the functions. Refer to Installing Extensions for more information.

Module Documentation

See sslinfo in the PostgreSQL documentation for detailed information about the individual functions in this module.

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7.4.25 tablefunc

The `tablefunc` module provides various functions that return tables (that is, multiple rows).

The WarehousePG `tablefunc` module is equivalent to the PostgreSQL `tablefunc` module. There are no WarehousePG or MPP-specific considerations for the module.

Installing and Registering the Module

The `tablefunc` module is installed when you install WarehousePG. Before you can use any of the functions defined in the module, you must register the `tablefunc` extension in each database in which you want to use the functions:

```
CREATE EXTENSION tablefunc;
```

Module Documentation

See tablefunc in the PostgreSQL documentation for detailed information about the individual functions in this module.

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7.4.26 timestamp9

The `timestamp9` module provides an efficient, nanosecond-precision timestamp data type and related functions and operators.

The WarehousePG `timestamp9` module is based on version 1.2.0 of the `timestamp9` module used with PostgreSQL.

Installing and Registering the Module

The `timestamp9` module is installed when you install WarehousePG. Before you can use the data type defined in the module, you must register the `timestamp9` extension in each database in which you want to use the type:

```
CREATE EXTENSION timestamp9;
```

Refer to Installing Extensions for more information.

Supported Data Types

The WarehousePG `timestamp9` extension supports three kinds of datatatypes: `TIMESTAMP9`, `TIMESTAMP9_LTZ` and `TIMESTAMP9_NTZ`. (The `TIMESTAMP9_LTZ` data type is an alias for `TIMESTAMP9` data type.)

The following table summarizes key information about the `timestamp9` data types:

Data Type	Storage Size	Description	Max Value	Min Value	Resolution
`TIMESTAMP9`	8 bytes	Like TIMESTAMP9_LTZ. Timestamp with local time zone.	2261-12-31 23:59:59.999999999 +0000	1700-01-01 00:00:00.000000000 +0000	1 nanosecond
`TIMESTAMP9_LTZ`	8 bytes	Timestamp with local time zone.	2261-12-31 23:59:59.999999999 +0000	1700-01-01 00:00:00.000000000 +0000	1 nanosecond
`TIMESTAMP9_NTZ`	8 bytes	Timestamp without time zone.	2261-12-31 23:59:59.999999999 +0000	1700-01-01 00:00:00.000000000 +0000	1 nanosecond

More about `TIMESTAMP9`

The `TIMESTAMP9` data type is identical to the `TIMESTAMP9_LTZ` data type. Please see the next section for details.

More about `TIMESTAMP9_LTZ`

`LTZ` is an abbreviation for "Local Time Zone." WarehousePG stores `TIMESTAMP9_LTZ` internally in UTC (Universal Coordinated Time, traditionally known as Greenwich Mean Time or GMT) time. An input value that has an explicit time zone specified is converted to UTC using the appropriate offset for that time zone.

If no time zone is specified in the input string, then it is presumed to be in the time zone indicated by the system's `TIMEZONE` server configuration parameter and is converted to UTC using the offset for the time zone.

See TIMESTAMP9_LTZ Examples for examples using this data type.

More about `TIIMESTAMP9_NTZ`

`NTZ` is an abbreviation of 'No Time Zone.' WarehousePG stores UTC time internally without considering any time zone information. If a time zone is embedded in the timestamp string, WarehousePG will simply ignore it.

See TIMESTAMP9_NTZ Examples for examples using this data type.

Supported Type Conversions

The following table summarizes the `timestamp9` module's supported type conversions.

From	To	Description
`BIGINT`	`TIMESTAMP9_LTZ`	WarehousePG treats the `BIGINT` value as the number of nanoseconds started from '1970-01-01 00:00:00 +0000'.
`DATE`	`TIMESTAMP9_LTZ`	WarehousePG treats the `DATE` value as in the current session time zone. This behavior is identical to converting from from `DATE` to `TIMESTAMPTZ`.
`TIMESTAMP WITHOUT TIME ZONE/TIMESTAMP`	`TIMESTAMP9_LTZ`	WarehousePG treats the `TIMESTAMP` value as in the current session time zone. This behavior is identical to converting from `TIMESTAMP` to `TIMESTAMPTZ`.
`TIMESTAMP WITH TIME ZONE/TIMESTAMPTZ`	`TIMESTAMP9_LTZ`	For this conversion, WarehousePG only extends the fractional part to nanosecond precision.
`TIMESTAMP9_LTZ`	`BIGINT`	The result of this conversion is the nanoseconds since '1970-01-01 00:00:00.000000000 +0000' to the given `TIMESTAMP9_LTZ` value. If the given `TIMESTAMP9_LTZ` value is before '1970-01-01 00:00:00.000000000 +0000', the result is negative.
`TIMESTAMP9_LTZ`	`DATE`	The result of this conversion depends on the date of the given `TIMESTAMP9_LTZ` value in the time zone of the current session. The behavior is like doing conversion from `TIMESTAMPTZ` to `DATE`.
`TIMESTAMP9_LTZ`	`TIMESTAMP WITHOUT TIME ZONE/TIMESTAMP`	The result of this conversion is a timestamp without time zone. The resulting timestamp's value is determined by the value of `TIMESTAMP9_LTZ` in the current session time zone. Note that the fractional part of `TIMESTAMP` type has 6 digits, while `TIMESTAMP9_LTZ` has 9 digits in its fractional part. When converting `TIMESTAMP9_LTZ` to `TIMESTAMP`, the fractional part is truncated instead of being rounded off.

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From	To	Description
`TIMESTAMP9_LTZ`	`TIMESTAMP WITH TIME ZONE/TIMESTAMP`	When performing this conversion, WarehousePG truncates the fractional part to only 6 digits.
`BIGINT`	`TIMESTAMP9_NTZ`	When performing this conversion, WarehousePG treats the BIGINT value as the number of nanoseconds started from '1970-01-01 00:00:00'.
`DATE`	`TIMESTAMP9_NTZ`	When performing this conversion, the resulting timestamp is '00:00:00.000000000' on the given date.
`TIMESTAMP WITHOUT TIME ZONE/TIMESTAMP`	`TIMESTAMP9_NTZ`	When peforming this conversion, WarehousePG only extends the fractional part to nanosecond precision.
`TIMESTAMP WITH TIME ZONE/TIMESTAMP`	`TIMESTAMP9_NTZ`	The resulting timestamp's value is determined by the value of `TIMESTAMPTZ` in the current session time zone.
`TIMESTAMP9_NTZ`	`BIGINT`	The result of this conversion is the nanoseconds since '1970-01-01 00:00:00.000000000' to the given `TIMESTAMP9_NTZ` value. If the given `TIMESTAMP9_NTZ` value is before '1970-01-01 00:00:00.000000000', the result is negative.
`TIMESTAMP9_NTZ`	`DATE`	When performing this conversion, WarehousePG truncatest the time portion and preserves the date portion.
`TIMESTAMP9_NTZ`	`TIMESTAMP WITHOUT TIME ZONE/TIMESTAMP`	When performing this conversion, WarehousePG truncates only the fractional part to 6 digits.
`TIMESTAMP9_NTZ`	`TIMESTAMP WITH TIME ZONE/TIMESTAMP`	When performing this conversion, WarehousePG only truncates the fractional part to 6 digits and add the time zone of the current session.
`TIMESTAMP9_LTZ`	`TIMESTAMP9_NTZ`	The resulting `TIMESTAMP9_NTZ` value is determined by the value of `TIMESTAMP9_LTZ` in the current session's time zone.
`TIMESTAMP9_NTZ`	`TIMESTAMP9_LTZ`	When performing this conversion, WarehousePG adds the timezone of the current sesion.

Type Conversion Examples

Convert `BIGINT` to `TIMESTAMP9_LTZ`

```
=# SHOW TIMEZONE;

   TimeZone
--------------
Asia/Shanghai
(1 row)

=# SELECT 0::BIGINT::TIMESTAMP9_LTZ;

           timestamp9_ltz
-------------------------------------
1970-01-01 08:00:00.000000000 +0800
(1 row)
```

Convert `DATE` to `TIMESTAMP9_LTZ`

```
=# SHOW TIMEZONE;

   TimeZone
--------------
Asia/Shanghai
(1 row)

 =# SELECT '2023-01-01'::DATE::TIMESTAMP9_LTZ;

           timestamp9_ltz
-------------------------------------
2023-01-01 00:00:00.000000000 +0800
(1 row)

=# SELECT '2023-01-01'::DATE::TIMESTAMPTZ;

      timestamptz
------------------------
2023-01-01 00:00:00+08
(1 row)
```

Convert `TIMESTAMP WITHOUT TIME ZONE/TIMESTAMP` to `TIMESTAMP9_LTZ`

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```
=# SHOW TIMEZONE;

   TimeZone
---------------
Asia/Shanghai
(1 row)

Time: 0.411 ms
=# SELECT '2023-01-01 00:00:00'::TIMESTAMP::TIMESTAMP9_LTZ;

           timestamp9_ltz
---------------------------------------
2023-01-01 00:00:00.000000000 +0800
(1 row)

Time: 0.691 ms
=# SELECT '2023-01-01 00:00:00'::TIMESTAMP::TIMESTAMPTZ;

      timestamptz
------------------------
2023-01-01 00:00:00+08
(1 row)
```

Convert `TIMESTAMP WITH TIME ZONE/TIMESTAMP` to `TIMESTAMP9_LTZ`

```
=# SELECT '2023-01-01 00:00:00.123456'::TIMESTAMPTZ::TIMESTAMP9_LTZ;

           timestamp9_ltz
---------------------------------------
2023-01-01 00:00:00.123456000 +0800
(1 row)
```

Convert `TIMESTAMP9_LTZ` to `BIGINT`

```
=# SELECT '2023-01-01 00:00:00.123456 Asia/Shanghai'::TIMESTAMP9_LTZ::BIGINT;

        int8
---------------------
1672502400123456000
(1 row)

=# SELECT '1969-01-01 00:00:00.123456 Asia/Shanghai'::TIMESTAMP9_LTZ::BIGINT;

        int8
--------------------
-31564799876544000
(1 row)
```

Convert `TIMESTAMP9_LTZ` to `DATE`

```
=# SET TIMEZONE TO 'Asia/Shanghai';
SET
=# SELECT '2023-01-02 02:59:59 Asia/Shanghai'::TIMESTAMPTZ::DATE;
    date
------------
2023-01-02
(1 row)

=# SET TIMEZONE TO 'UTC+0';
SET
=# SELECT '2023-01-02 02:59:59 Asia/Shanghai'::TIMESTAMPTZ::DATE;
    date
------------
2023-01-01
(1 row)
```

Convert `TIMESTAMP9_LTZ` to `TIMESTAMP WITHOUT TIME ZONE/TIMESTAMP`

Example 1

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```
=# SET TIMEZONE TO 'Asia/Shanghai';
SET
=# SELECT '2023-01-02 02:59:59 Asia/Shanghai'::TIMESTAMP9_LTZ::TIMESTAMP;

      timestamp
---------------------
2023-01-02 02:59:59
(1 row)

=# SET TIMEZONE TO 'UTC+0';

SET
=# SELECT '2023-01-02 02:59:59 Asia/Shanghai'::TIMESTAMP9_LTZ::TIMESTAMP;

      timestamp
---------------------
2023-01-01 18:59:59
(1 row)
```

Example 2 -- Truncation of the fractional part

```
=# SET TIMEZONE TO 'Asia/Shanghai';
SET
=# SELECT '2023-01-02 02:59:59.123456789 Asia/Shanghai'::TIMESTAMP9_LTZ::TIMESTAMP;

         timestamp
----------------------------
2023-01-02 02:59:59.123456
(1 row)
```

Convert `TIMESTAMP9_LTZ` to `TIMESTAMP WITH TIME ZONE/TIMESTAMP`

```
=# SET TIMEZONE TO 'Asia/Shanghai';
=# SELECT '2023-01-02 02:59:59.123456789 Asia/Shanghai'::TIMESTAMP9_LTZ::TIMESTAMPTZ;
          timestamptz
-------------------------------
2023-01-02 02:59:59.123456+08
(1 row)
```

Convert `BIGINT` to `TIMESTAMP9_NTZ`

```
=# SELECT 0::BIGINT::TIMESTAMP9_NTZ;
        timestamp9_ntz
-------------------------------

1970-01-01 00:00:00.000000000
(1 row)
```

Convert `DATE` to `TIMESTAMP9_NTZ`

```
=# SELECT '2023-01-01'::DATE::TIMESTAMP9_NTZ;
        timestamp9_ntz
-------------------------------
2023-01-01 00:00:00.000000000
(1 row)
```

Convert `TIMESTAMP WITHOUT TIME ZONE/TIMESTAMP` to `TIMESTAMP9_NTZ`

```
=# SELECT '2023-01-01 00:00:00.123456'::TIMESTAMP::TIMESTAMP9_NTZ;
        timestamp9_ntz

-------------------------------
2023-01-01 00:00:00.123456000
(1 row)
```

Convert `TIMESTAMP WITH TIME ZONE/TIMESTAMP` to `TIMESTAMP9_NTZ`

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```
=# SET TIMEZONE TO 'Asia/Shanghai';
SET
=# SELECT '2023-01-01 00:00:00.123456 Asia/Shanghai'::TIMESTAMPTZ::TIMESTAMP9_NTZ;
        timestamp9_ntz
-------------------------------
2023-01-01 00:00:00.123456000
(1 row)

=# SET TIMEZONE TO 'UTC+0';
SET
=# SELECT '2023-01-01 00:00:00.123456 Asia/Shanghai'::TIMESTAMPTZ::TIMESTAMP9_NTZ;
        timestamp9_ntz
-------------------------------
2022-12-31 16:00:00.123456000
(1 row)
```

Convert `TIMESTAMP9_NTZ` to `BIGINT`

```
=# SELECT '2023-01-01 00:00:00.123456'::TIMESTAMP9_NTZ::BIGINT;
        int8
---------------------
1672531200123456000
(1 row)

=# SELECT '1969-01-01 00:00:00.123456'::TIMESTAMP9_NTZ::BIGINT;
        int8
--------------------
-31535999876544000
(1 row)
```

Convert `TIMESTAMP9_NTZ` to `DATE`

```
=# SELECT '2023-01-01 00:00:00.123456'::TIMESTAMP9_NTZ::DATE;
    date
------------
2023-01-01
(1 row)
```

Convert `TIMESTAMP9_NTZ` to `TIMESTAMP WITHOUT TIME ZONE/TIMESTAMP`

```
=# SELECT '2023-01-01 00:00:00.123456789'::TIMESTAMP9_NTZ::TIMESTAMP;
         timestamp
----------------------------
2023-01-01 00:00:00.123456
(1 row)
```

Convert `TIMESTAMP9_NTZ` to `TIMESTAMP WITH TIME ZONE/TIMESTAMP`

```
=# SET TIMEZONE TO 'Asia/Shanghai';
SET
=# SELECT '2023-01-01 23:00:00.123456789'::TIMESTAMP9_NTZ::TIMESTAMPTZ;
          timestamptz
-------------------------------
2023-01-01 23:00:00.123456+08
(1 row)

Time: 0.793 ms
=# SET TIMEZONE TO 'UTC+0';
SET
=# SELECT '2023-01-01 23:00:00.123456789'::TIMESTAMP9_NTZ::TIMESTAMPTZ;
          timestamptz
-------------------------------
2023-01-01 23:00:00.123456+00
(1 row)
```

Convert `TIMESTAMP9_LTZ` to `TIMESTAMP9_NTZ`

```
=# SET TIMEZONE TO 'Asia/Shanghai';
SET
=# SELECT '2023-01-01 23:00:00.123456789 Asia/Shanghai'::TIMESTAMP9_LTZ::TIMESTAMP9_NTZ;
        timestamp9_ntz
-------------------------------
2023-01-01 23:00:00.123456789
(1 row)

=# SET TIMEZONE TO 'UTC+0';
SET
=# SELECT '2023-01-01 23:00:00.123456789 Asia/Shanghai'::TIMESTAMP9_LTZ::TIMESTAMP9_NTZ;
        timestamp9_ntz
-------------------------------
2023-01-01 15:00:00.123456789
(1 row)
```

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Convert `TIMESTAMP9_NTZ` to `TIMESTAMP9_LTZ`

```
=# SET TIMEZONE TO 'Asia/Shanghai';
SET
=# SELECT '2023-01-01 23:00:00.123456789'::TIMESTAMP9_NTZ::TIMESTAMP9_LTZ;
           timestamp9_ltz
-------------------------------------
2023-01-01 23:00:00.123456789 +0800
(1 row)

=# SET TIMEZONE TO 'UTC+0';
SET
=# SELECT '2023-01-01 23:00:00.123456789'::TIMESTAMP9_NTZ::TIMESTAMP9_LTZ;
           timestamp9_ltz
-------------------------------------
2023-01-01 23:00:00.123456789 +0000
(1 row)
```

The TimeZone Configuration Parameter and `timestamp9`

You can set the TimeZone server configuration parameter to specify the time zone that WarehousePG uses when it prints a `timestamp9` timestamp. When you set this parameter, WarehousePG displays the timestamp value in that time zone. For example:

```
testdb=# SELECT
now()::timestamp9;

now
-------------------------------------
 2022-08-24 18:08:01.729360000 +0800
(1 row)

testdb=# SET timezone TO
'UTC+2';
SET
testdb=# SELECT
now()::timestamp9;

now
-------------------------------------
 2022-08-24 08:08:12.995542000 -0200
(1 row)
```

Support For Date/Time Functions

The `timestamp9` module defines two server configuration parameters that you set to enable date/time functions defined in the `pg_catalog` schema on `timestamp` types. Visit the PostgreSQL Documentation for a list of the supported date/time functions. The parameters are:

- `timestamp9.enable_implicit_cast_timestamp9_ltz_to_timestamptz` : when enabled, casting a `timestamp9_ltz` value to `timestamp with time zone` becomes implicit.
- `timestamp9.enable_implicit_cast_timestamp9_ntz_to_timestamp` : when enabled, casting a `timestamp9_ntz` value to `timestamp without time zone` becomes implicit.

The default value for both configuration parameters is `off`. For example, if you try use the `date` function with `timestamp9` and `timestamp9.enable_implicit_cast_timestamp9_ltz_to_timestamptz` is set to `off`:

```
postgres=# SELECT date('2022-01-01'::timestamp9_ltz);
ERROR:  implicitly cast timestamp9_ltz to timestamptz is not allowed
HINT:  either set 'timestamp9.enable_implicit_cast_timestamp9_ltz_to_timestamptz' to 'on' or do it explicitly
```

Enable the configuration parameter in order to use the `date` function:

```
postgres=# SET timestamp9.enable_implicit_cast_timestamp9_ltz_to_timestamptz TO 'ON';
SET
postgres=# SELECT date('2022-01-01'::timestamp9_ltz);
    date
------------
 01-01-2022
(1 row)
```

Note that enabling these configuration parameters will also result in multiple casting paths from `timestamp9` types and built-in `timestamp` types. You may encounter error messages such as:

```
postgres=# select '2019-09-19'::timestamp9_ltz <= '2019-09-20'::timestamptz;
ERROR:  operator is not unique: timestamp9_ltz <= timestamp with time zone
LINE 1: select '2019-09-19'::timestamp9_ltz <= '2019-09-20'::timesta...
HINT:  Could not choose a best candidate operator. You might need to add explicit type casts.
```

In this situation, cast the type explicitly:

```
postgres=# select '2019-09-19'::timestamp9_ntz <= '2019-09-20'::timestamptz::timestamp9_ntz;
?column?
----------
 t
(1 row)
```

Alternatively, cast the `timestamp9_ntz` value to the `timestamptz` value:

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```
postgres=# select '2019-09-19'::timestamp9_ntz::timestamptz <= '2019-09-20'::timestamptz;
?column?
----------
 t
(1 row)
```

Support For Date/Time Functions

The `timestamp9` module defines two server configuration parameters that you set to enable date/time functions defined in the `pg_catalog` schema on `timestamp` types. Visit the PostgreSQL Documentation for a list of the supported date/time functions. The parameters are:

- `timestamp9.enable_implicit_cast_timestamp9_ltz_to_timestamptz` : when enabled, casting a `timestamp9_ltz` value to `timestamp with time zone` becomes implicit.
- `timestamp9.enable_implicit_cast_timestamp9_ntz_to_timestamp` : when enabled, casting a `timestamp9_ntz` value to `timestamp without time zone` becomes implicit.

The default value for both configuration parameters is `off` . For example, if you try use the `date` function with `timestamp9` and `timestamp9.enable_implicit_cast_timestamp9_ltz_to_timestamptz` is set to `off` :

```
postgres=# SELECT date('2022-01-01'::timestamp9_ltz);
ERROR:  implicitly cast timestamp9_ltz to timestamptz is not allowed
HINT:  either set 'timestamp9.enable_implicit_cast_timestamp9_ltz_to_timestamptz' to 'on' or do it explicitly
```

Enable the configuration parameter in order to use the `date` function:

```
postgres=# SET timestamp9.enable_implicit_cast_timestamp9_ltz_to_timestamptz TO 'ON';
SET
postgres=# SELECT date('2022-01-01'::timestamp9_ltz);
    date
------------
 01-01-2022
(1 row)
```

Note that enabling these configuration parameters will also result in multiple casting paths from `timestamp9` types and built-in `timestamp` types. You may encounter error messages such as:

```
postgres=# select '2019-09-19'::timestamp9_ltz <= '2019-09-20'::timestamptz;
ERROR:  operator is not unique: timestamp9_ltz <= timestamp with time zone
LINE 1: select '2019-09-19'::timestamp9_ltz <= '2019-09-20'::timesta...
HINT:  Could not choose a best candidate operator. You might need to add explicit type casts.
```

In this situation, cast the type explicitly:

```
postgres=# select '2019-09-19'::timestamp9_ntz <= '2019-09-20'::timestamptz::timestamp9_ntz;
?column?
----------
 t
(1 row)
```

Alternatively, cast the `timestamp9_ntz` value to the `timestamptz` value:

```
postgres=# select '2019-09-19'::timestamp9_ntz::timestamptz <= '2019-09-20'::timestamptz;
?column?
----------
 t
(1 row)
```

Examples

`TIMESTAMP9_LTZ` Examples

Valid input for `TIMESTAMP9_LTZ`

Valid input for the `TIMESTAMP9_LTZ` consists of the concatenation of a date and a time, followed by an optional time zone. Users can specify the fractional part of second up to 9 digits (in nanosecond precision).

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```
The current system's TIMEZONE parameter is 'Asia/Shanghai'

SELECT '2023-02-20 00:00:00.123456789 +0200'::TIMESTAMP9_LTZ;

           timestamp9_ltz

---------------------------------------
2023-02-20 06:00:00.123456789 +0800
(1 row)

 If the input string doesn't have explicit time zone information, the timestamp is presumed to be in the time zone indicated by the system's TIMEZONE parameter.

SELECT '2023-02-20 00:00:00.123456789'::TIMESTAMP9_LTZ;

           timestamp9_ltz
---------------------------------------
2023-02-20 00:00:00.123456789 +0800
(1 row)
```

TIMESTAMP9_LTZ also accepts numbers as valid input. It's interpreted as the number of nanoseconds since the UTC time '1970-01-01 00:00:00.000000000'.

```
SELECT '123456789'::TIMESTAMP9_LTZ;

           timestamp9_ltz
---------------------------------------
1970-01-01 08:00:00.123456789 +0800
(1 row)
```

`TIMESTAMP9_NTZ` Examples

Valid input for `TIMESTAMP9_NTZ`

As with `TIMESTAMP9_LTZ`, valid input for the `TIMESTAMP9_NTZ` data type consists of the concatenation of a date and a time, followed by an optional time zone. Users can specify the fractional part of second up to 9 digits (in nanosecond precision). The difference is that, if the user specifies time zone in the input string, `TIMESTAMP9_NTZ` will ignore it and store the remaining timestamp as UTC time without applying any time zone offset.

The current system's TIMEZONE parameter is 'Asia/Shanghai'

```
=# SELECT '2023-02-20 00:00:00.123456789 +0200'::TIMESTAMP9_NTZ;
        timestamp9_ntz
-------------------------------
2023-02-20 00:00:00.123456789
(1 row)
=# SELECT '2023-02-20 00:00:00.123456789'::TIMESTAMP9_NTZ;
        timestamp9_ntz
-------------------------------
2023-02-20 00:00:00.123456789
(1 row)
```

Limitations

The `timestamp9` data type does not support arithmetic calculations with nanoseconds.

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7.4.27 uuid-ossp

The `uuid-ossp` module provides functions to generate universally unique identifiers (UUIDs) using one of several standard algorithms. The module also includes functions to produce certain special UUID constants.

The WarehousePG `uuid-ossp` module is equivalent to the PostgreSQL `uuid-ossp` module. There are no WarehousePG or MPP-specific considerations for the module.

Installing and Registering the Module

The `uuid-ossp` module is installed when you install WarehousePG. Before you can use any of the functions defined in the module, you must register the `uuid-ossp` extension in each database in which you want to use the functions:

```
CREATE EXTENSION "uuid-ossp";
```

Refer to Installing Extensions for more information.

Module Documentation

See the PostgreSQL uuid-ossp documentation for detailed information about this module.

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7.4.28 isn

The `isn` module provides support for the international product numbering standards EAN13, UPC, ISBN (books), ISMN (music), and ISSN (serials).

The WarehousePG `isn` module is equivalent to version 1.2 of the `isn` module used with PostgreSQL. There are no WarehousePG or MPP-specific considerations for the module.

Installing and Registering the Module

The `isn` module is installed when you install WarehousePG. Before you can use any of the numbering standards defined in the module, you must register the `isn` extension in each database in which you want to use the standards:

```
CREATE EXTENSION isn;
```

Refer to Installing Extensions for more information.

Module Documentation

Refer to the isn Postgres documentation for detailed information about using the module.

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7.4.29 pgaudit

The PostgreSQL Audit Extension, or `pgaudit`, provides detailed session and object audit logging via the standard logging facility provided by PostgreSQL. The goal of PostgreSQL Audit is to provide the tools needed to produce audit logs required to pass certain government, financial, or ISO certification audits.

Installing and Registering the Module

The `pgaudit` module is installed when you install WarehousePG. To use it, enable the extension as a preloaded library and restart WarehousePG.

First, check if there are any preloaded shared libraries by running the following command:

```
gpconfig -s shared_preload_libraries
```

Use the output of the above command to enable the `pgaudit` module, along any other shared libraries, and restart WarehousePG:

```
gpconfig -c shared_preload_libraries -v '<other_libraries>,pgaudit'
gpstop -ar
```

Module Documentation

Refer to the pgaudit github documentation for detailed information about using the module.

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7.4.30 pgvector

A machine language-generated embedding is a complex object transformed into a list of numbers (vector) that reflects both the semantic and syntactic relationships of the data. The `pgvector` module provides vector similarity search capabilities for WarehousePG that enable you to search, store, and query embeddings at large scale.

The WarehousePG `pgvector` module is equivalent to version 0.5.1 of the `pgvector` module used with PostgreSQL. The limitations of the WarehousePG version of the module are described in theWarehousePG Limitations topic.

Installing and Registering the Module

The `pgvector` module is installed when you install WarehousePG. Before you can use the data type and index access method defined in the module, you must register the `vector` extension in each database in which you want to use these:

```
CREATE EXTENSION vector;
```

Refer to Installing Extensions for more information.

Upgrading the Module

The `pgvector` module is installed when you install or upgrade WarehousePG. A previous version of the extension will continue to work in existing databases after you upgrade WarehousePG. To upgrade to the most recent version of the extension, you must:

```
ALTER EXTENSION vector UPDATE TO '0.5.1';
```

in **every** database in which you registered/use the extension.

About the vector Types, Operators, and Functions

`pgvector` provides a `vector` data type and the index access methods `ivfflat` and `hnsw`. The type, methods, and the supporting functions and operators provided by the module enable you to perform exact and approximate neighbor search on, and determine L2, inner product, and cosine distance between, embeddings. You can also use the module to store and query embeddings.

vector Data Type

The `vector` data type represents an n-dimensional coordinate. Each `vector` takes `4 * dimensions + 8` bytes of storage. Each element is a single precision floating-point number (similar to the `real` type in WarehousePG), and all of the elements must be finite (no `NaN`, `Infinity`, or `-Infinity`). Vectors can have up to 16,000 dimensions.

vector Operators

`pgvector` provides the following operators for the `vector` data type:

Operator	Description
+	Element-wise addition
-	Element-wise subtraction
*	Element-wise multiplication
<->	Euclidean distance
<#>[1]	Negative inner product
<=>	Cosine distance

[1] Because WarehousePG supports only `ASC` order index scans on operators, `<#>` returns the *negative* inner product.

vector Functions

`pgvector` provides the following functions for the `vector data type:

Function Name	Description
cosine_distance(vector, vector) → double precision	Computes the cosine distance
inner_product(vector, vector) → double precision	Computes the inner product
l2_distance(vector, vector) → double precision	Computes the Euclidean distance
l1_distance(vector, vector) → double precision	Computes the taxicab distance
vector_dims(vector) → integer	Returns the number of dimensions
vector_norm(vector) → double precision	Computes the Euclidean norm

vector Aggregate Functions

`pgvector` provides the following aggregate functions for the `vector` data type:

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Function	Description
avg(vector) → vector	Computes the arithmetic mean
sum(vector) → vector	Computes the sum of the vector elements

Using the pgvector Module

You can use `pgvector` to search, store, and query embeddings in WarehousePG.

Examples: Storing Embeddings in WarehousePG

In the following examples, you manipulate a `vector` column of a table.

Create a new table with a `vector` column with 3 dimensions:

```
CREATE TABLE items (id bigserial PRIMARY KEY, embedding
vector(3));
```

Or add a `vector` column to an existing table:

```
ALTER TABLE items ADD COLUMN embedding vector(3);
```

Insert `vector`s into the table:

```
INSERT INTO items (embedding) VALUES ('[1,2,3]'),
('[4,5,6]');
```

Upsert `vector`s:

```
INSERT INTO items (id, embedding) VALUES (1, '[1,2,3]'), (2,
'[4,5,6]')
    ON CONFLICT (id) DO UPDATE SET embedding =
EXCLUDED.embedding;
```

Update `vector`s:

```
UPDATE items SET embedding = '[1,2,3]' WHERE id = 1;
```

Delete `vector`s:

```
DELETE FROM items WHERE id = 1;
```

Examples: Querying Embeddings in WarehousePG

You can query embeddings as follows.

Get the nearest neighbors to a `vector` by L2 distance:

```
SELECT * FROM items ORDER BY embedding <-> '[3,1,2]' LIMIT 5;
```

Get the nearest neighbors to a row:

```
SELECT * FROM items WHERE id != 1
  ORDER BY embedding <-> (SELECT embedding FROM items WHERE id = 1) LIMIT
5;
```

Get rows within a certain distance:

```
SELECT * FROM items WHERE embedding <-> '[3,1,2]' < 5;
```

Combine with the `ORDER BY` and `LIMIT` clauses to use an index.

Evaluating Embedding Distance

The following examples use the available `vector` distance operators.

Get the distance:

```
SELECT embedding <-> '[3,1,2]' AS distance FROM
items;
```

When you request the inner product, remember to multiply by `-1`:

```
SELECT (embedding <#> '[3,1,2]') * -1 AS inner_product FROM
items;
```

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For cosine similarity, use `1 - <cosine_distance>`:

```
SELECT 1 - (embedding <=> '[3,1,2]') AS cosine_similarity FROM
items;
```

Aggregating Embeddings

The following examples display various forms of aggregating embeddings.

Average the vectors in a table:

```
SELECT AVG(embedding) FROM
items;
```

Average a group of vectors in a table:

```
SELECT category_id, AVG(embedding) FROM items GROUP BY category_id;
```

About Indexing Embeddings

By default, `pgvector` performs exact nearest neighbor search, which provides perfect recall. You can add an index to use approximate nearest neighbor search, trading some recall for performance.

> **Note** Unlike a typical index, a query returns different results after adding an approximate index.

When you create an index for an embedding, you use the `lists` parameter to specify the number of *clusters* created during index creation. Each cluster is a partition of the data set.

To achieve good recall, keep the following in mind:

1. Create the index *after* the table has some data.
2. Choose an appropriate number of `lists`. A reasonable initial value is `rows / 1000` for up to 1M rows and `sqrt(rows)` for over 1M rows.
3. When querying, specify an appropriate number of probes (higher is better for recall, lower is better for speed). A reasonable initial value is `sqrt(lists)`.

The following examples show how to add an index for various distance methods.

IVFFlat Examples

Create an index on the L2 distance:

```
CREATE INDEX ON items USING ivfflat (embedding vector_l2_ops) WITH (lists =
100);
```

Create an index on the inner product:

```
CREATE INDEX ON items USING ivfflat (embedding vector_ip_ops) WITH (lists =
100);
```

Create an index on the cosine distance:

```
CREATE INDEX ON items USING ivfflat (embedding vector_cosine_ops) WITH (lists =
100);
```

You can index a `vector` that has up to 2,000 dimensions.

Query Options

`pgvector` provides a `probes` parameter that you can set at query time to specify the number of regions to search during a query.

Specify the number of `probes` (1 by default):

```
SET ivfflat.probes =
10;
```

A higher `probes` value provides better recall at the cost of speed. You can set it to the number of `lists` for exact nearest neighbor search (at which point the planner will not use the index).

Use `SET LOCAL` inside a transaction block to set `probes` for a single query:

```
BEGIN;
SET LOCAL ivfflat.probes =
10;
SELECT ...
COMMIT;
```

HNSW Examples

Create an index on the L2 distance:

```
CREATE INDEX ON items USING hnsw (embedding vector_l2_ops);
```

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Create an index on the inner product:

```
CREATE INDEX ON items USING hnsw (embedding vector_ip_ops);
```

Create an index on the cosine distance:

```
CREATE INDEX ON items USING hnsw (embedding
vector_cosine_ops);
```

You can index a `vector` that has up to 2,000 dimensions.

HNSW indexes support the following parameters:

- `m` specifies the maximum number of connections per layer (16 by default)
- `ef_construction` specifies the size of the dynamic candidate list for constructing the graph (64 by default)

For example:

```
CREATE INDEX ON items USING hnsw (embedding vector_l2_ops) WITH (m = 16, ef_construction = 64);
```

Query Options

Specify a csutom size for the dynamic candidate list for a search:

```
SET hnsw.ef_search = 100;
```

Higher value provides better recall at the cost of speed. The default size of the candidate list is 40.

This example sets the candidate size in a transaction for a single query:

```
BEGIN;
SET LOCAL hnsw.ef_search = 100;
SELECT ...
COMMIT;
```

Indexing Progress

You can check index creation progress in WarehousePG as described in CREATE INDEX Progress Reporting.

```
SELECT phase, tuples_done, tuples_total FROM
gp_stat_progress_create_index;
```

Filtering

There are multiple ways to index nearest neighbor queries with a `WHERE` clause:

```
SELECT * FROM items WHERE category_id = 123 ORDER BY embedding <-> '[3,1,2]' LIMIT
5;
```

For exact search, create an index on one or more of the `WHERE` columns:

```
CREATE INDEX ON items
(category_id);
```

For approximate search, create a partial index on the `vector` column:

```
CREATE INDEX ON items USING ivfflat (embedding vector_l2_ops) WITH (lists =
100)
    WHERE (category_id = 123);
```

Use partitioning for approximate search on many different values of the `WHERE` columns:

```
CREATE TABLE items (embedding vector(3), category_id int) PARTITION BY
LIST(category_id);
```

About Hybrid Search

You can use `pgvector` together with full-text search for a hybrid search:

```
SELECT id, content FROM items, to_tsquery('hello & search')
query
    WHERE textsearch @@ query ORDER BY ts_rank_cd(textsearch, query) DESC LIMIT 5;
```

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About Debugging and Maximizing Performance

Use EXPLAIN ANALYZE to debug performance:

```
EXPLAIN ANALYZE SELECT * FROM items ORDER BY embedding <-> '[3,1,2]' LIMIT 5;
```

Exact Search

To speed up queries without an index, increase the `max_parallel_workers_per_gather` server configuration parameter:

```
SET max_parallel_workers_per_gather =
4;
```

If vectors are normalized to length `1`, use inner product for the best performance:

```
SELECT * FROM items ORDER BY embedding <#> '[3,1,2]' LIMIT 5;
```

Approximate Search

To speed up queries with an index, increase the number of inverted `lists` (at the expense of recall):

```
CREATE INDEX ON items USING ivfflat (embedding vector_l2_ops) WITH (lists =
1000);
```

WarehousePG Limitations

`pgvector` for WarehousePG has the following limitations:

- The WarehousePG query optimizer (GPORCA) does not support `ivfflat` and `hnsw` vector indexes. Queries on tables that utilize these index types fall back to the Postgres-based planner.
- Append-optimized tables cannot use vector indexes.
- The size of (a vector) index can be larger than the table size.

Additional References

The following examples use `pgvector` and the WarehousePG documentation to build an AI assistant for the product documentation:

- Building large-scale AI-powered search in WarehousePG using pgvector and OpenAI
- ask-warehousepg

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7.4.31 tsm_system_rows

The `tsm_system_rows` module implements the `SYSTEM_ROWS` table sampling method. This method is used in the `TABLESAMPLE` clause of a `SELECT` command.

The `tsm_system_rows` module is a WarehousePG extension.

Installing and Registering the Module

The `tsm_system_rows` module is installed when you install WarehousePG. Before you can use any of the functions defined in the module, you must register the `tsm_system_rows` extension in each database where you want to use the functions. Refer to Installing Extensions for more information.

Using the tsm_system_rows Module

The `SYSTEM ROWS` table sampling method accepts a single integer argument that is the maximum number of rows to read. The resulting sample will always contain exactly that many rows, unless the table does not contain enough rows, in which case the whole table is selected.

Like the built-in `SYSTEM` sampling method, `SYSTEM_ROWS` performs block-level sampling, so that the sample is not completely random but may be subject to clustering effects, especially if only a small number of rows are requested.

Example

The following command returns a sample of 75 rows from the table `tableA`, unless the table does not have 75 visible rows; in this case, the command returns all table rows:

```
SELECT * FROM tableA TABLESAMPLE SYSTEM_ROWS(75);
```

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7.4.32 tsm_system_time

The `tsm_system_time` module implements the `SYSTEM_TIME` table sampling method. This method is used in the `TABLESAMPLE` clause of a `SELECT` command.

The `tsm_system_time` module is a WarehousePG extension.

Installing and Registering the Module

The `tsm_system_time` module is installed when you install WarehousePG. Before you can use any of the functions defined in the module, you must register the `tsm_system_time` extension in each database where you want to use the functions. Refer to Installing Extensions for more information.

Using the tsm_system_time Module

The `SYSTEM_TIME` table sampling method takes a single floating-point argument that specifies the maximum number of milliseconds to spend reading the table. This allows you to control how long the query takes; the tradeoff is that the size of the sample becomes hard to predict. The resulting sample will contain as many rows as could be read in the specified time, unless the whole table has been read first.

Like the built-in `SYSTEM` sampling method, `SYSTEM_TIME` performs block-level sampling, so that, rather than being completely random, the sample may be subject to clustering effects, particularly when a small number of rows are selected.

Example

The following command return as large a sample of `tableA` as it can read in 1/2 second (500 milliseconds). If the entire table can be read in under 1 second, all of its rows will be returned.

```
SELECT * FROM tableA TABLESAMPLE SYSTEM_TIME(500);
```

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7.5 Character Set Support

The character set support in WarehousePG allows you to store text in a variety of character sets, including single-byte character sets such as the ISO 8859 series and multiple-byte character sets such as EUC (Extended Unix Code), UTF-8, and Mule internal code. All supported character sets can be used transparently by clients, but a few are not supported for use within the server (that is, as a server-side encoding). The default character set is selected while initializing your WarehousePG cluster using `gpinitsystem`. It can be overridden when you create a database, so you can have multiple databases each with a different character set.

Name	Description	Language	Server?	Bytes/Char	Aliases
BIG5	Big Five	Traditional Chinese	No	1-2	WIN950, Windows950
EUC_CN	Extended UNIX Code-CN	Simplified Chinese	Yes	1-3	
EUC_JP	Extended UNIX Code-JP	Japanese	Yes	1-3	
EUC_KR	Extended UNIX Code-KR	Korean	Yes	1-3	
EUC_TW	Extended UNIX Code-TW	Traditional Chinese, Taiwanese	Yes	1-3	
GB18030	National Standard	Chinese	No	1-2	
GBK	Extended National Standard	Simplified Chinese	No	1-2	WIN936, Windows936
ISO_8859_5	ISO 8859-5, ECMA 113	Latin/Cyrillic	Yes	1	
ISO_8859_6	ISO 8859-6, ECMA 114	Latin/Arabic	Yes	1	
ISO_8859_7	ISO 8859-7, ECMA 118	Latin/Greek	Yes	1	
ISO_8859_8	ISO 8859-8, ECMA 121	Latin/Hebrew	Yes	1	
JOHAB	JOHA	Korean (Hangul)	Yes	1-3	
KOI8	KOI8-R(U)	Cyrillic	Yes	1	KOI8R
LATIN1	ISO 8859-1, ECMA 94	Western European	Yes	1	ISO88591
LATIN2	ISO 8859-2, ECMA 94	Central European	Yes	1	ISO88592
LATIN3	ISO 8859-3, ECMA 94	South European	Yes	1	ISO88593
LATIN4	ISO 8859-4, ECMA 94	North European	Yes	1	ISO88594
LATIN5	ISO 8859-9, ECMA 128	Turkish	Yes	1	ISO88599
LATIN6	ISO 8859-10, ECMA 144	Nordic	Yes	1	ISO885910
LATIN7	ISO 8859-13	Baltic	Yes	1	ISO885913
LATIN8	ISO 8859-14	Celtic	Yes	1	ISO885914
LATIN9	ISO 8859-15	LATIN1 with Euro and accents	Yes	1	ISO885915
LATIN10	ISO 8859-16, ASRO SR 14111	Romanian	Yes	1	ISO885916
MULE_INTERNAL	Mule internal code	Multilingual Emacs	Yes	1-4	
SJIS	Shift JIS	Japanese	No	1-2	Mskanji, ShiftJIS, WIN932, Windows932
SQL_ASCII	unspecified	any	No	1	
UHC	Unified Hangul Code	Korean	No	1-2	WIN949, Windows949
UTF8	Unicode, 8-bit	all	Yes	1-4	Unicode
WIN866	Windows CP866	Cyrillic	Yes	1	ALT
WIN874	Windows CP874	Thai	Yes	1	
WIN1250	Windows CP1250	Central European	Yes	1	
WIN1251	Windows CP1251	Cyrillic	Yes	1	WIN
WIN1252	Windows CP1252	Western European	Yes	1	
WIN1253	Windows CP1253	Greek	Yes	1	
WIN1254	Windows CP1254	Turkish	Yes	1	
WIN1255	Windows CP1255	Hebrew	Yes	1	
WIN1256	Windows CP1256	Arabic	Yes	1	
WIN1257	Windows CP1257	Baltic	Yes	1	
WIN1258	Windows CP1258	Vietnamese	Yes	1	ABC, TCVN, TCVN5712, VSCII

Parent topic: WarehousePG Reference Guide

Setting the Character Set

`gpinitsystem` defines the default character set for a WarehousePG cluster by reading the setting of the `ENCODING` parameter in the `gp_init_config` file at initialization time. The default character set is `UNICODE` or `UTF8`.

You can create a database with a different character set besides what is used as the system-wide default. For example:

```
=> CREATE DATABASE korean WITH ENCODING 'EUC_KR';
```

> **Important** Although you can specify any encoding you want for a database, it is unwise to choose an encoding that is not what is expected by the locale you have selected. The `LC_COLLATE` and `LC_CTYPE` settings imply a particular encoding, and locale-dependent operations (such as sorting) are likely to misinterpret data that is in an incompatible encoding.

Since these locale settings are frozen by `gpinitsystem`, the apparent flexibility to use different encodings in different databases is more theoretical than real.

One way to use multiple encodings safely is to set the locale to `C` or `POSIX` during initialization time, thus deactivating any real locale awareness.

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Character Set Conversion Between Server and Client

WarehousePG supports automatic character set conversion between server and client for certain character set combinations. The conversion information is stored in the coordinator*pg_conversion* system catalog table. WarehousePG comes with some predefined conversions or you can create a new conversion using the SQL command `CREATE CONVERSION`.

Server Character Set	Available Client Character Sets
BIG5	not supported as a server encoding
EUC_CN	EUC_CN, MULE_INTERNAL, UTF8
EUC_JP	EUC_JP, MULE_INTERNAL, SJIS, UTF8
EUC_KR	EUC_KR, MULE_INTERNAL, UTF8
EUC_TW	EUC_TW, BIG5, MULE_INTERNAL, UTF8
GB18030	not supported as a server encoding
GBK	not supported as a server encoding
ISO_8859_5	ISO_8859_5, KOI8, MULE_INTERNAL, UTF8, WIN866, WIN1251
ISO_8859_6	ISO_8859_6, UTF8
ISO_8859_7	ISO_8859_7, UTF8
ISO_8859_8	ISO_8859_8, UTF8
JOHAB	JOHAB, UTF8
KOI8	KOI8, ISO_8859_5, MULE_INTERNAL, UTF8, WIN866, WIN1251
LATIN1	LATIN1, MULE_INTERNAL, UTF8
LATIN2	LATIN2, MULE_INTERNAL, UTF8, WIN1250
LATIN3	LATIN3, MULE_INTERNAL, UTF8
LATIN4	LATIN4, MULE_INTERNAL, UTF8
LATIN5	LATIN5, UTF8
LATIN6	LATIN6, UTF8
LATIN7	LATIN7, UTF8
LATIN8	LATIN8, UTF8
LATIN9	LATIN9, UTF8
LATIN10	LATIN10, UTF8
MULE_INTERNAL	MULE_INTERNAL, BIG5, EUC_CN, EUC_JP, EUC_KR, EUC_TW, ISO_8859_5, KOI8, LATIN1 to LATIN4, SJIS, WIN866, WIN1250, WIN1251
SJIS	not supported as a server encoding
SQL_ASCII	not supported as a server encoding
UHC	not supported as a server encoding
UTF8	all supported encodings
WIN866	WIN866
ISO_8859_5	KOI8, MULE_INTERNAL, UTF8, WIN1251
WIN874	WIN874, UTF8
WIN1250	WIN1250, LATIN2, MULE_INTERNAL, UTF8
WIN1251	WIN1251, ISO_8859_5, KOI8, MULE_INTERNAL, UTF8, WIN866
WIN1252	WIN1252, UTF8
WIN1253	WIN1253, UTF8
WIN1254	WIN1254, UTF8
WIN1255	WIN1255, UTF8
WIN1256	WIN1256, UTF8
WIN1257	WIN1257, UTF8
WIN1258	WIN1258, UTF8

To enable automatic character set conversion, you have to tell WarehousePG the character set (encoding) you would like to use in the client. There are several ways to accomplish this:

- Using the `\encoding` command in `psql`, which allows you to change client encoding on the fly.
- Using `SET client_encoding TO`.

  To set the client encoding, use the following SQL command:

  ```
  => SET CLIENT_ENCODING TO '*value*';
  ```

  To query the current client encoding:

  ```
  => SHOW client_encoding;
  ```

  To return to the default encoding:

  ```
  => RESET client_encoding;
  ```

- Using the `PGCLIENTENCODING` environment variable. When `PGCLIENTENCODING` is defined in the client's environment, that client encoding is automatically selected when a connection to the server is made. (This can subsequently be overridden using any of the other methods mentioned above.)
- Setting the configuration parameter `client_encoding`. If `client_encoding` is set in the coordinator `postgresql.conf` file, that client encoding is automatically selected when a connection to WarehousePG is made. (This can subsequently be overridden using any of the other methods mentioned above.)

If the conversion of a particular character is not possible (suppose you chose `EUC_JP` for the server and `LATIN1` for the client, then some Japanese characters do not have a representation in `LATIN1`) then an error is reported.

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If the client character set is defined as `SQL_ASCII`, encoding conversion is deactivated, regardless of the server's character set. The use of `SQL_ASCII` is unwise unless you are working with all-ASCII data. `SQL_ASCII` is not supported as a server encoding.

[1] Not all APIs support all the listed character sets. For example, the JDBC driver does not support MULE_INTERNAL, LATIN6, LATIN8, and LATIN10.[2] The SQL_ASCII setting behaves considerably differently from the other settings. Byte values 0-127 are interpreted according to the ASCII standard, while byte values 128-255 are taken as uninterpreted characters. If you are working with any non-ASCII data, it is unwise to use the SQL_ASCII setting as a client encoding. SQL_ASCII is not supported as a server encoding.

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7.6 Server Configuration Parameters

There are many WarehousePG server configuration parameters that affect the behavior of the WarehousePG cluster. Many of these configuration parameters have the same names, settings, and behaviors as in a regular PostgreSQL database system.

- Parameter Types and Values describes the parameter data types and values.
- Setting Parameters describes limitations on who can change them and where or when they can be set.
- Parameter Categories organizes parameters by functionality.
- Configuration Parameters lists the parameter descriptions in alphabetic order.

Parameter Types and Values

All parameter names are case-insensitive. Every parameter takes a value of one of the following types: `Boolean`, `integer`, `floating point`, `enum`, or `string`.

Boolean values may be specified as `ON`, `OFF`, `TRUE`, `FALSE`, `YES`, `NO`, `1`, `0` (all case-insensitive).

Enum-type parameters are specified in the same manner as string parameters, but are restricted to a limited set of values. Enum parameter values are case-insensitive.

Some settings specify a memory size or time value. Each of these has an implicit unit, which is either kilobytes, blocks (typically eight kilobytes), milliseconds, seconds, or minutes. Valid memory size units are `kB` (kilobytes), `MB` (megabytes), and `GB` (gigabytes). Valid time units are `ms` (milliseconds), `s` (seconds), `min` (minutes), `h` (hours), and `d` (days). Note that the multiplier for memory units is 1024, not 1000. A valid time expression contains a number and a unit. When specifying a memory or time unit using the `SET` command, enclose the value in quotes. For example:

```
SET statement_mem TO '200MB';
```

> **Note** There is no space between the value and the unit names.

Setting Parameters

> **Note** WarehousePG does not support using the `ALTER SYSTEM` command to set server configuration parameters.

Many of the configuration parameters have limitations on who can change them and where or when they can be set. For example, to change certain parameters, you must be a WarehousePG superuser. Other parameters require a restart of the system for the changes to take effect. A parameter that is classified as *session* can be set at the system level (in the `postgresql.conf` file), at the database-level (using `ALTER DATABASE`), at the role-level (using `ALTER ROLE`), at the database- and role-level (`ALTER ROLE...IN DATABASE...SET`, or at the session-level (using `SET`). System parameters can only be set in the `postgresql.conf` file.

In WarehousePG, the coordinator and each segment instance has its own `postgresql.conf` file (located in their respective data directories). Some parameters are considered *local* parameters, meaning that each segment instance looks to its own `postgresql.conf` file to get the value of that parameter. You must set local parameters on every instance in the system (coordinator and segments). Others parameters are considered *coordinator* parameters. Coordinator parameters need only be set at the coordinator instance.

This table describes the values in the Settable Classifications column of the table in the description of a server configuration parameter.

Set Classification	Description
coordinator or local	A *coordinator* parameter only needs to be set in the `postgresql.conf` file of the WarehousePG coordinator instance. The value for this parameter is then either passed to (or ignored by) the segments at run time. A local parameter must be set in the `postgresql.conf` file of the coordinator AND each segment instance. Each segment instance looks to its own configuration to get the value for the parameter.
session or system	*Session* parameters can be changed on the fly within a database session, and can have a hierarchy of settings: at the system level (`postgresql.conf`), at the database level (`ALTER DATABASE...SET`), at the role level (`ALTER ROLE...SET`), at the database and role level (`ALTER ROLE...IN DATABASE...SET`), or at the session level (`SET`). If the parameter is set at multiple levels, then the most granular setting takes precedence (for example, session overrides database and role, database and role overrides role, role overrides database, and database overrides system). A *system* parameter can only be changed via the `postgresql.conf` file(s).
restart or reload	When changing parameter values in the postgresql.conf file(s), some require a *restart* of WarehousePG for the change to take effect. Other parameter values can be refreshed by just reloading the server configuration file (using `gpstop -u`), and do not require stopping the system.
superuser	These session parameters can only be set by a database superuser. Regular database users cannot set this parameter.
read only	These parameters are not settable by database users or superusers. The current value of the parameter can be shown but not altered.

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7.6.1 Configuration Parameters

Descriptions of the WarehousePG server configuration parameters listed alphabetically.

application_name

Sets the application name for a client session. For example, if connecting via `psql`, this will be set to `psql`. Setting an application name allows it to be reported in log messages and statistics views.

Value Range	Default	Set Classifications
string		coordinator, session, reload

array_nulls

This controls whether the array input parser recognizes unquoted NULL as specifying a null array element. By default, this is on, allowing array values containing null values to be entered. WarehousePG versions before 3.0 did not support null values in arrays, and therefore would treat NULL as specifying a normal array element with the string value 'NULL'.

Value Range	Default	Set Classifications
Boolean	on	coordinator, session, reload

authentication_timeout

Maximum time to complete client authentication. This prevents hung clients from occupying a connection indefinitely.

Value Range	Default	Set Classifications
Any valid time expression (number and unit)	1min	local, system, restart

autovacuum

When enabled, WarehousePG starts up the autovacuum daemon, which operates at the database level. When the daemon is running, WarehousePG:

- Automatically vacuums catalog tables and possibly auxiliary tables (determined by the gp_autovacuum_scope configuration parameter setting).
- Automatically analyzes the vacuumed tables.

Value Range	Default	Set Classifications
Boolean	on	coordinator, system, restart

autovacuum_analyze_scale_factor

Specifies a fraction of the table size to add to `autovacuum_analyze_threshold` when deciding whether or not to trigger an `ANALYZE`. The default is 0.1 (10% of table size). This parameter may be set only in the `postgresql.conf file` or on the server command line; but the setting can be overridden for individual tables by changing table storage parameters.

Value Range	Default	Set Classifications
Floating point	0.1	coordinator, system, restart

autovacuum_analyze_threshold

Specifies the minimum number of inserted, updated or deleted tuples needed to trigger an `ANALYZE` in any one table. The default is 50 tuples. This parameter may be set only in the `postgresql.conf` file or on the server command line; but the setting can be overridden for individual tables by changing table storage parameters.

Value Range	Default	Set Classifications
Integer	50	coordinator, system, restart

autovacuum_freeze_max_age

Specifies the maximum age at which to automatically vacuum a table to prevent transaction ID wraparound. Note that the system will launch autovacuum processes to prevent wraparound even wher `autovacuum=off`. The default value is 200 million transactions.

Value Range	Default	Set Classifications
100000 < integer < 2000000000	200000000	local, system, restart

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autovacuum_max_workers

Specifies the maximum number of autovacuum processes (other than the autovacuum launcher) that may be running at any one time. The default is three. This parameter may be set only at server start.

Value Range	Default	Set Classifications
Integer	3	coordinator, system, restart

autovacuum_multixact_freeze_max_age

Specifies the maximum age (in multixacts) that a table's `pg_class.relminmxid` field can attain before a `VACUUM` operation is forced to prevent multixact ID wraparound within the table. Note that the system will launch autovacuum processes to prevent wraparound even when autovacuum is otherwise disabled.

Vacuuming multixacts also allows removal of old files from the `pg_multixact/members` and `pg_multixact/offsets subdirectories`, which is why the default is a relatively low 400 million multixacts. This parameter may be set only at server start, but the setting can be reduced for individual tables by changing table storage parameters.

Value Range	Default	Set Classifications
Integer	400000000	coordinator, system, restart

autovacuum_naptime

When `autovacuum=on` (the default), specifies the minimum delay between autovacuum runs. In each round, the daemon issues `VACUUM` and `ANALYZE` commands as needed for catalog (and possibly auxiliary) tables.

A value without units is taken to be seconds. The default is one minute.

This parameter may be set only in the `postgresql.conf` file or on the server command line.

Value Range	Default	Set Classifications
1 < integer < INT_MAX/1000	60	coordinator, system, restart

autovacuum_vacuum_cost_delay

Specifies the cost delay value in milliseconds for automatic vacuum operations. If set to -1, the value of this parameter is the set by `vacuum_cost_delay`.

A value without units is taken to be milliseconds. The default is 2 milliseconds. This parameter may be set only in the `postgresql.conf` file or on the server command line.

Value Range	Default	Set Classifications
floating point < 100	2	local, system, reload

autovacuum_vacuum_cost_limit

Specifies the cost limit value that will be used in automatic `VACUUM` operations. If -1 is specified (which is the default), the regular `vacuum_cost_limit` value will be used. Note that the value is distributed proportionally among the running autovacuum workers, if there is more than one, so that the sum of the limits for each worker does not exceed the value of this variable. This parameter may be set only in the `postgresql.conf` file or on the server command line; but the setting can be overridden for individual tables by changing table storage parameters.

Value Range	Default	Set Classifications
Integer	-1	local, system, reload

autovacuum_vacuum_scale_factor

Specifies a fraction of the table size to add to `autovacuum_vacuum_threshold` when deciding whether to trigger a `VACUUM`. The default is 0.2 (20% of table size). This parameter may be set only in the `postgresql.conf` file or on the server command line.

Value Range	Default	Set Classifications
floating point (%)	0.05	local, system, reload

autovacuum_vacuum_threshold

Specifies the minimum number of updated or deleted tuples needed to trigger a `VACUUM` in any one table. The default is 50 tuples. This parameter can only be set in the postgresql.conf file or on the server command line.

Value Range	Default	Set Classifications
0 < integer < INT_MAX	500	local, system, reload

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backslash_quote

This controls whether a quote mark can be represented by \' in a string literal. The preferred, SQL-standard way to represent a quote mark is by doubling it (') but PostgreSQL has historically also accepted \'. However, use of \' creates security risks because in some client character set encodings, there are multibyte characters in which the last byte is numerically equivalent to ASCII \.

Value Range	Default	Set Classifications
on (allow \' always), off (reject always), safe_encoding (allow only if client encoding does not allow ASCII \ within a multibyte character)	safe_encoding	coordinator, session, reload

block_size

Reports the size of a disk block.

Value Range	Default	Set Classifications
number of bytes	32768	read only

bonjour_name

Specifies the Bonjour broadcast name. By default, the computer name is used, specified as an empty string. This option is ignored if the server was not compiled with Bonjour support.

Value Range	Default	Set Classifications
string	unset	coordinator, system, restart

check_function_bodies

When set to off, deactivates validation of the function body string during `CREATE FUNCTION`. Deactivating validation is occasionally useful to avoid problems such as forward references when restoring function definitions from a dump.

Value Range	Default	Set Classifications
Boolean	on	coordinator, session, reload

checkpoint_completion_target

Specifies the target of checkpoint completion, as a fraction of the total time between checkpoints. The default is `0.5`.

You can set this parameter only in the `postgresql.conf` file or on the server command line.

Value Range	Default	Set Classifications
0.0 - 1.0 (floating point)	0.5	local, system, reload

checkpoint_flush_after

Specifies the number of pages after which WarehousePG flushes previously performed writes to disk. Whenever more than the specified amount of data has been written while performing a checkpoint, WarehousePG attempts to force the operating system to issue these writes to the underlying storage. Doing so limits the amount of dirty data in the kernel's page cache, reducing the likelihood of stalls when an `fsync` is issued at the end of the checkpoint, or when the OS writes data back in larger batches in the background. Often that results in greatly reduced transaction latency, but note that there are some cases where performance may degrade, especially with workloads that are bigger than shared_buffers, but smaller than the OS's page cache.

If you specify this value without units, it is taken as blocks, that is `BLCKSZ` bytes (typically 32kB). The valid range is between `0`, which disables forced writeback, and `256`. The default is `32`.

You can set this parameter only in the `postgresql.conf` file or on the server command line.

Value Range	Default	Set Classifications
0 - 256 (integer)	32	local, system, reload

checkpoint_timeout

Specifies the maximum time between automatic WAL checkpoints.

If you specify this value without units, it is taken as seconds. The valid range is between 30 seconds and one day. The default value is five minutes `5min` or `300`).

Increasing this parameter can increase the amount of time needed for crash recovery.

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Value Range	Default	Set Classifications
30 - 86400 (integer)	300	local, system, reload

checkpoint_warning

Enables warnings if checkpoint segments are filled more frequently than the specified value. WarehousePG writes a message to the server log if checkpoints caused by the filling of WAL segment files happen closer together than this amount of time (which suggests that you should raise max_wal_size).

If you specify this value without units, it is taken as seconds. The default is 30 seconds (`30`). The value zero (`0`) disables the warning.

WarehousePG generates no warnings if checkpoint_timeout is less than `checkpoint_warning`.

You can set this parameter only in the `postgresql.conf` file or on the server command line.

Value Range	Default	Set Classifications
0 - `INT_MAX` (integer)	30	local, system, reload

client_connection_check_interval

Sets the time interval between optional checks that the client is still connected, while running queries. 0 deactivates connection checks.

Value Range	Default	Set Classifications
number of milliseconds	0	coordinator, session, reload

client_encoding

Sets the client-side encoding (character set). The default is to use the same as the database encoding. See Supported Character Sets in the PostgreSQL documentation.

Value Range	Default	Set Classifications
character set	UTF8	coordinator, session, reload

client_min_messages

Controls which message levels are sent to the client. Each level includes all the levels that follow it. The later the level, the fewer messages are sent.

Value Range	Default	Set Classifications
DEBUG5, DEBUG4, DEBUG3, DEBUG2, DEBUG1, LOG, NOTICE, WARNING, ERROR, FATAL, PANIC	NOTICE	coordinator, session, reload

`INFO` level messages are always sent to the client.

cpu_index_tuple_cost

For the Postgres-based planner, sets the estimate of the cost of processing each index row during an index scan. This is measured as a fraction of the cost of a sequential page fetch.

Value Range	Default	Set Classifications
floating point	0.005	coordinator, session, reload

cpu_operator_cost

For the Postgres-based planner, sets the estimate of the cost of processing each operator in a WHERE clause. This is measured as a fraction of the cost of a sequential page fetch.

Value Range	Default	Set Classifications
floating point	0.0025	coordinator, session, reload

cpu_tuple_cost

For the Postgres-based planner, Sets the estimate of the cost of processing each row during a query. This is measured as a fraction of the cost of a sequential page fetch.

Value Range	Default	Set Classifications
floating point	0.01	coordinator, session, reload

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cursor_tuple_fraction

Tells the Postgres-based planner how many rows are expected to be fetched in a cursor query, thereby allowing the Postgres-based planner to use this information to optimize the query plan. The default of 1 means all rows will be fetched.

Value Range	Default	Set Classifications
integer	1	coordinator, session, reload

data_checksums

Reports whether checksums are enabled for heap data storage in the database system. Checksums for heap data are enabled or deactivated when the database system is initialized and cannot be changed.

Heap data pages store heap tables, catalog tables, indexes, and database metadata. Append-optimized storage has built-in checksum support that is unrelated to this parameter.

WarehousePG uses checksums to prevent loading data corrupted in the file system into memory managed by database processes. When heap data checksums are enabled, WarehousePG computes and stores checksums on heap data pages when they are written to disk. When a page is retrieved from disk, the checksum is verified. If the verification fails, an error is generated and the page is not permitted to load into managed memory.

If the `ignore_checksum_failure` configuration parameter has been set to on, a failed checksum verification generates a warning, but the page is allowed to be loaded into managed memory. If the page is then updated, it is flushed to disk and replicated to the mirror. This can cause data corruption to propagate to the mirror and prevent a complete recovery. Because of the potential for data loss, the `ignore_checksum_failure` parameter should only be enabled when needed to recover data. See ignore_checksum_failure for more information.

Value Range	Default	Set Classifications
Boolean	on	read only

DateStyle

Sets the display format for date and time values, as well as the rules for interpreting ambiguous date input values. This variable contains two independent components: the output format specification and the input/output specification for year/month/day ordering.

Value Range	Default	Set Classifications
<format>, <date style> where: <format> is ISO, Postgres, SQL, or German <date style> is DMY, MDY, or YMD	ISO, MDY	coordinator, session, reload

db_user_namespace

This enables per-database user names. If on, you should create users as *username@dbname*. To create ordinary global users, simply append @ when specifying the user name in the client.

Value Range	Default	Set Classifications
Boolean	off	local, system, restart

deadlock_timeout

The time to wait on a lock before checking to see if there is a deadlock condition. On a heavily loaded server you might want to raise this value. Ideally the setting should exceed your typical transaction time, so as to improve the odds that a lock will be released before the waiter decides to check for deadlock.

Value Range	Default	Set Classifications
Any valid time expression (number and unit)	1s	local, system, restart

debug_assertions

Turns on various assertion checks.

Value Range	Default	Set Classifications
Boolean	off	local, system, restart

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debug_pretty_print

Indents debug output to produce a more readable but much longer output format. *client_min_messages* or *log_min_messages* must be DEBUG1 or lower.

Value Range	Default	Set Classifications
Boolean	on	coordinator, session, reload

debug_print_parse

For each query run, prints the resulting parse tree. *client_min_messages* or *log_min_messages* must be DEBUG1 or lower.

Value Range	Default	Set Classifications
Boolean	off	coordinator, session, reload

debug_print_plan

For each query run, prints the WarehousePG parallel query execution plan. *client_min_messages* or *log_min_messages* must be DEBUG1 or lower.

Value Range	Default	Set Classifications
Boolean	off	coordinator, session, reload

debug_print_prelim_plan

For each query run, prints the preliminary query plan. *client_min_messages* or *log_min_messages* must be DEBUG1 or lower.

Value Range	Default	Set Classifications
Boolean	off	coordinator, session, reload

debug_print_rewritten

For each query run, prints the query rewriter output. *client_min_messages* or *log_min_messages* must be DEBUG1 or lower.

Value Range	Default	Set Classifications
Boolean	off	coordinator, session, reload

debug_print_slice_table

For each query run, prints the WarehousePG query slice plan. *client_min_messages* or *log_min_messages* must be DEBUG1 or lower.

Value Range	Default	Set Classifications
Boolean	off	coordinator, session, reload

debug_shareinput_xslice

Prints cross-slice share input scan information to the server log.

Value Range	Default	Set Classifications
Boolean	off	coordinator, session, reload, superuser

default_statistics_target

Sets the default statistics sampling target (the number of values that are stored in the list of common values) for table columns that have not had a column-specific target set via `ALTER TABLE SET STATISTICS`. Larger values may improve the quality of the Postgres-based planner estimates, particularly for columns with irregular data distributions, at the expense of consuming more space in `pg_statistic` and slightly more time to compute the estimates. Conversely, a lower limit might be sufficient for columns with simple data distributions. The default is 100.

For more information on the use of statistics by the Postgres-based planner, refer to Statistics Used by the Planner in the PostgreSQL documentation.

Value Range	Default	Set Classifications
0 > Integer > 10000	100	coordinator, session, reload

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default_table_access_method

Sets the default table access method when a `CREATE TABLE` command does not explicitly specify an access method.

Value Range	Default	Set Classifications
heap, ao_row, ao_column	heap	coordinator, session

default_tablespace

The default tablespace in which to create objects (tables and indexes) when a `CREATE` command does not explicitly specify a tablespace.

Value Range	Default	Set Classifications
name of a tablespace	unset	coordinator, session, reload

default_text_search_config

Selects the text search configuration that is used by those variants of the text search functions that do not have an explicit argument specifying the configuration. See Using Full Text Search for further information. The built-in default is `pg_catalog.simple`, but `initdb` will initialize the configuration file with a setting that corresponds to the chosen `lc_ctype` locale, if a configuration matching that locale can be identified.

Value Range	Default	Set Classifications
The name of a text search configuration.	`pg_catalog.simple`	coordinator, session, reload

default_transaction_deferrable

When running at the `SERIALIZABLE` isolation level, a deferrable read-only SQL transaction may be delayed before it is allowed to proceed. However, once it begins running it does not incur any of the overhead required to ensure serializability; so serialization code will have no reason to force it to abort because of concurrent updates, making this option suitable for long-running read-only transactions.

This parameter controls the default deferrable status of each new transaction. It currently has no effect on read-write transactions or those operating at isolation levels lower than `SERIALIZABLE`. The default is `off`.

> **Note** Setting `default_transaction_deferrable` to `on` has no effect in WarehousePG. Only read-only, `SERIALIZABLE` transactions can be deferred. However, WarehousePG does not support the `SERIALIZABLE` transaction isolation level. See SET TRANSACTION.

Value Range	Default	Set Classifications
Boolean	off	coordinator, session, reload

default_transaction_isolation

Controls the default isolation level of each new transaction. WarehousePG treats `read uncommitted` the same as `read committed`, and treats `serializable` the same as `repeatable read`.

Value Range	Default	Set Classifications
read committed, read uncommitted, repeatable read, serializable	read committed	coordinator, session, reload

default_transaction_read_only

Controls the default read-only status of each new transaction. A read-only SQL transaction cannot alter non-temporary tables.

Value Range	Default	Set Classifications
Boolean	off	coordinator, session, reload

dynamic_library_path

If a dynamically loadable module needs to be opened and the file name specified in the `CREATE FUNCTION` or `LOAD` command does not have a directory component (i.e. the name does not contain a slash), the system will search this path for the required file. The compiled-in PostgreSQL package library directory is substituted for $libdir. This is where the modules provided by the standard PostgreSQL distribution are installed.

Value Range	Default	Set Classifications
a list of absolute directory paths separated by colons	$libdir	local, system, reload

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effective_cache_size

Sets the assumption about the effective size of the disk cache that is available to a single query for the Postgres-based planner. This is factored into estimates of the cost of using an index; a higher value makes it more likely index scans will be used, a lower value makes it more likely sequential scans will be used. When setting this parameter, you should consider both WarehousePG's shared buffers and the portion of the kernel's disk cache that will be used for data files (though some data might exist in both places). Take also into account the expected number of concurrent queries on different tables, since they will have to share the available space. This parameter has no effect on the size of shared memory allocated by a WarehousePG server instance, nor does it reserve kernel disk cache; it is used only for estimation purposes.

Set this parameter to a number of block_size blocks (default 32K) with no units; for example, `262144` for 8GB. You can also directly specify the size of the effective cache; for example, `'1GB'` specifies a size of 32768 blocks. The `gpconfig` utility and `SHOW` command display the effective cache size value in units such as 'GB', 'MB', or 'kB'.

Value Range	Default	Set Classifications
1 - INT_MAX *or* number and unit	524288 (16GB)	coordinator, session, reload

enable_bitmapscan

Activates or deactivates the use of bitmap-scan plan types by the Postgres-based planner. Note that this is different than a Bitmap Index Scan. A Bitmap Scan means that indexes will be dynamically converted to bitmaps in memory when appropriate, giving faster index performance on complex queries against very large tables. It is used when there are multiple predicates on different indexed columns. Each bitmap per column can be compared to create a final list of selected tuples.

Value Range	Default	Set Classifications
Boolean	on	coordinator, session, reload

enable_groupagg

Activates or deactivates the use of group aggregation plan types by the Postgres-based planner.

Value Range	Default	Set Classifications
Boolean	on	coordinator, session, reload

enable_hashagg

Activates or deactivates the use of hash aggregation plan types by the Postgres-based planner.

Value Range	Default	Set Classifications
Boolean	on	coordinator, session, reload

enable_hashjoin

Activates or deactivates the use of hash-join plan types by the Postgres-based planner.

Value Range	Default	Set Classifications
Boolean	on	coordinator, session, reload

enable_indexscan

Activates or deactivates the use of index-scan plan types by the Postgres-based planner.

Value Range	Default	Set Classifications
Boolean	on	coordinator, session, reload

enable_mergejoin

Activates or deactivates the use of merge-join plan types by the Postgres-based planner. Merge join is based on the idea of sorting the left- and right-hand tables into order and then scanning them in parallel. So, both data types must be capable of being fully ordered, and the join operator must be one that can only succeed for pairs of values that fall at the 'same place' in the sort order. In practice this means that the join operator must behave like equality.

Value Range	Default	Set Classifications
Boolean	off	coordinator, session, reload

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enable_nestloop

Activates or deactivates the use of nested-loop join plans by the Postgres-based planner. It's not possible to suppress nested-loop joins entirely, but turning this variable off discourages the Postgres-based planner from using one if there are other methods available.

Value Range	Default	Set Classifications
Boolean	off	coordinator, session, reload

enable_partition_pruning

Enables or disables the query planner's ability to eliminate a partitioned table's partitions from query plans. This also controls the planner's ability to generate query plans which allow the query executor to remove (ignore) partitions during query execution.

Value Range	Default	Set Classifications
Boolean	on	coordinator, session, reload

enable_seqscan

Activates or deactivates the use of sequential scan plan types by the Postgres-based planner. It's not possible to suppress sequential scans entirely, but turning this variable off discourages the Postgres-based planner from using one if there are other methods available.

Value Range	Default	Set Classifications
Boolean	on	coordinator, session, reload

enable_sort

Activates or deactivates the use of explicit sort steps by the Postgres-based planner. It's not possible to suppress explicit sorts entirely, but turning this variable off discourages the Postgres-based planner from using one if there are other methods available.

Value Range	Default	Set Classifications
Boolean	on	coordinator, session, reload

enable_tidscan

Activates or deactivates the use of tuple identifier (TID) scan plan types by the Postgres-based planner.

Value Range	Default	Set Classifications
Boolean	on	coordinator, session, reload

escape_string_warning

When on, a warning is issued if a backslash (\) appears in an ordinary string literal ('...' syntax). Escape string syntax (E'...') should be used for escapes, because in future versions, ordinary strings will have the SQL standard-conforming behavior of treating backslashes literally.

Value Range	Default	Set Classifications
Boolean	on	coordinator, session, reload

explain_pretty_print

Determines whether EXPLAIN VERBOSE uses the indented or non-indented format for displaying detailed query-tree dumps.

Value Range	Default	Set Classifications
Boolean	on	coordinator, session, reload

extra_float_digits

Adjusts the number of digits displayed for floating-point values, including float4, float8, and geometric data types. The parameter value is added to the standard number of digits. The value can be set as high as 3, to include partially-significant digits; this is especially useful for dumping float data that needs to be restored exactly. Or it can be set negative to suppress unwanted digits.

Value Range	Default	Set Classifications
integer (-15 to 3)	0	coordinator, session, reload

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from_collapse_limit

The Postgres-based planner will merge sub-queries into upper queries if the resulting FROM list would have no more than this many items. Smaller values reduce planning time but may yield inferior query plans.

Value Range	Default	Set Classifications
1-*n*	20	coordinator, session, reload

gin_pending_list_limit

Sets the maximum size of a GIN index's pending list, which is used when `fastupdate` is enabled. If the list grows larger than this maximum size, it is cleaned up by moving the entries in it to the index's main GIN data structure in bulk.

A value specified without units is taken to be kilobytes. The default is four megabytes (4MB).

You can override this setting for individual GIN indexes by changing index storage parameters.

Value Range	Default	Set Classifications
64 - `MAX_KILOBYTES`	4096	coordinator, session, reload

gp_adjust_selectivity_for_outerjoins

Enables the selectivity of NULL tests over outer joins.

Value Range	Default	Set Classifications
Boolean	on	coordinator, session, reload

gp_appendonly_compaction

Enables compacting segment files during `VACUUM` commands. When deactivated, `VACUUM` only truncates the segment files to the EOF value, as is the current behavior. The administrator may want to deactivate compaction in high I/O load situations or low space situations.

Value Range	Default	Set Classifications
Boolean	on	coordinator, session, reload

gp_appendonly_compaction_threshold

Specifies the threshold ratio (as a percentage) of hidden rows to total rows that triggers compaction of the segment file when VACUUM is run without the FULL option (a lazy vacuum). If the ratio of hidden rows in a segment file on a segment is less than this threshold, the segment file is not compacted, and a log message is issued.

Value Range	Default	Set Classifications
integer (%)	10	coordinator, session, reload

gp_autostats_allow_nonowner

The `gp_autostats_allow_nonowner` server configuration parameter determines whether or not to allow WarehousePG to trigger automatic statistics collection when a table is modified by a non-owner.

The default value is `false`; WarehousePG does not trigger automatic statistics collection on a table that is updated by a non-owner.

When set to `true`, WarehousePG will also trigger automatic statistics collection on a table when:

- `gp_autostats_mode=on_change` and the table is modified by a non-owner.
- `gp_autostats_mode=on_no_stats` and the first user to `INSERT` or `COPY` into the table is a non-owner.

The `gp_autostats_allow_nonowner` configuration parameter can be changed only by a superuser.

Value Range	Default	Set Classifications
Boolean	false	coordinator, session, reload, superuser

gp_autostats_lock_wait

The `gp_autostats_lock_wait` server configuration parameter allows you to control whether `ANALYZE` commands triggered by autostats collection will block if they cannot acquire the table lock.

The default value is `off`; `ANALYZE` commands will attempt locks on tables and, if unsuccessful, will proceed without possession of the table lock.

Keeping this parameter turned off will prevent deadlocks and make automatic statistics collection sessions finish in a more timely and predictable fashion.

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When set to `on`, the `ANALYZE` command will block until the table lock is acquired.

Value Range	Default	Set Classifications
Boolean	off	coordinator, session, session, reload

gp_autostats_mode

Specifies the mode for triggering automatic statistics collection with `ANALYZE`. The `on_no_stats` option triggers statistics collection for `CREATE TABLE AS SELECT`, `INSERT`, or `COPY` operations on any table that has no existing statistics.

The `on_change` option triggers statistics collection only when the number of rows affected exceeds the threshold defined by `gp_autostats_on_change_threshold`. Operations that can trigger automatic statistics collection with `on_change` are:

`CREATE TABLE AS SELECT`

`UPDATE`

`DELETE`

`INSERT`

`COPY`

Default is `none`.

> **Note** For partitioned tables, automatic statistics collection is not triggered if data is inserted from the top-level parent table of a partitioned table.

Automatic statistics collection is triggered if data is inserted directly in a leaf table (where the data is stored) of the partitioned table. Statistics are collected only on the leaf table.

Value Range	Default	Set Classifications
none, on_change, none,	on_no_ stats	coordinator, session, reload

gp_autostats_mode_in_functions

Specifies the mode for triggering automatic statistics collection with `ANALYZE` for statements in procedural language functions. The `none` option deactivates statistics collection. The `on_no_stats` option triggers statistics collection for `CREATE TABLE AS SELECT`, `INSERT`, or `COPY` operations that are run in functions on any table that has no existing statistics.

The `on_change` option triggers statistics collection only when the number of rows affected exceeds the threshold defined by `gp_autostats_on_change_threshold`. Operations in functions that can trigger automatic statistics collection with `on_change` are:

`CREATE TABLE AS SELECT`

`UPDATE`

`DELETE`

`INSERT`

`COPY`

Value Range	Default	Set Classifications
none, on_change, on_no_stats,	none	coordinator, session, reload

gp_autostats_on_change_threshold

Specifies the threshold for automatic statistics collection when `gp_autostats_mode` is set to `on_change`. When a triggering table operation affects a number of rows exceeding this threshold, `ANALYZE` is added and statistics are collected for the table.

Value Range	Default	Set Classifications
integer	2147483647	coordinator, session, reload

gp_autovacuum_scope

When `autovacuum=on` (the default), specifies the types of tables that are eligible for automatic vacuuming of dead tuples. WarehousePG supports two `gp_autovacuum_scope` values:

- `catalog` - WarehousePG autovacuums catalog tables only (`pg_catalog` relations).
- `catalog_ao_aux` - WarehousePG autovacuums catalog tables and append-optimized auxiliary tables (`pg_catalog`, `pg_toast`, and `pg_aoseg` relations).

Only superusers can change this setting.

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Value Range	Default	Set Classifications
catalog, catalog_ao_aux	catalog	coordinator, system, reload

gp_cached_segworkers_threshold

When a user starts a session with WarehousePG and issues a query, the system creates groups or 'gangs' of worker processes on each segment to do the work. After the work is done, the segment worker processes are destroyed except for a cached number which is set by this parameter. A lower setting conserves system resources on the segment hosts, but a higher setting may improve performance for power-users that want to issue many complex queries in a row.

Value Range	Default	Set Classifications
integer > 0	5	coordinator, session, reload

gp_command_count

Shows how many commands the coordinator has received from the client. Note that a single SQLcommand might actually involve more than one command internally, so the counter may increment by more than one for a single query. This counter also is shared by all of the segment processes working on the command.

Value Range	Default	Set Classifications
integer > 0	1	read only

gp_connection_send_timeout

Timeout for sending data to unresponsive WarehousePG user clients during query processing. A value of 0 deactivates the timeout, WarehousePG waits indefinitely for a client. When the timeout is reached, the query is cancelled with this message:

```
Could not send data to client: Connection timed out.
```

Value Range	Default	Set Classifications
number of seconds	3600 (1 hour)	coordinator, system, reload

gp_content

The local content id if a segment.

Value Range	Default	Set Classifications
integer		read only

gp_create_table_random_default_distribution

Controls table creation when a WarehousePG table is created with a CREATE TABLE or CREATE TABLE AS command that does not contain a DISTRIBUTED BY clause.

For CREATE TABLE, if the value of the parameter is `off` (the default), and the table creation command does not contain a DISTRIBUTED BY clause, WarehousePG chooses the table distribution key based on the command:

- If a `LIKE` or `INHERITS` clause is specified, then WarehousePG copies the distribution key from the source or parent table.
- If a `PRIMARY KEY` or `UNIQUE` constraints are specified, then WarehousePG chooses the largest subset of all the key columns as the distribution key.
- If neither constraints nor a `LIKE` or `INHERITS` clause is specified, then WarehousePG chooses the first suitable column as the distribution key. (Columns with geometric or user-defined data types are not eligible as WarehousePG distribution key columns.)

If the value of the parameter is set to `on`, WarehousePG follows these rules to create a table when the DISTRIBUTED BY clause is not specified:

- If PRIMARY KEY or UNIQUE columns are not specified, the distribution of the table is random (DISTRIBUTED RANDOMLY). Table distribution is random even if the table creation command contains the LIKE or INHERITS clause.
- If PRIMARY KEY or UNIQUE columns are specified, a DISTRIBUTED BY clause must also be specified. If a DISTRIBUTED BY clause is not specified as part of the table creation command, the command fails.

For a CREATE TABLE AS command that does not contain a distribution clause:

- If the Postgres-based planner creates the table, and the value of the parameter is `off`, the table distribution policy is determined based on the command.
- If the Postgres-based planner creates the table, and the value of the parameter is `on`, the table distribution policy is random.
- If GPORCA creates the table, the table distribution policy is random. The parameter value has no affect.

For information about the Postgres-based planner and GPORCA, see "SQL: Querying Data" in the *WarehousePG Administrator Guide*.

Value Range	Default	Set Classifications
boolean	off	coordinator, session, reload

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gp_dbid

The local content dbid of a segment.

Value Range	Default	Set Classifications
integer		read only

gp_debug_linger

Number of seconds for a WarehousePG process to linger after a fatal internal error.

Value Range	Default	Set Classifications
Any valid time expression (number and unit)	0	coordinator, session, reload

gp_default_storage_options

Set the default values for the following table storage options when a table is created with the `CREATE TABLE` command.

- appendoptimized

  > **Note** You use the `appendoptimized=value` syntax to specify the append-optimized table storage type. `appendoptimized` is a thin alias for the `appendonly` legacy storage option. WarehousePG stores `appendonly` in the catalog, and displays the same when listing the storage options for append-optimized tables.

- blocksize
- checksum
- compresstype
- compresslevel
- orientation

Specify multiple storage option values as a comma separated list.

You can set the storage options with this parameter instead of specifying the table storage options in the `WITH` of the `CREATE TABLE` command. The table storage options that are specified with the `CREATE TABLE` command override the values specified by this parameter.

Not all combinations of storage option values are valid. If the specified storage options are not valid, an error is returned. See the `CREATE TABLE` command for information about table storage options.

The defaults can be set for a database and user. If the server configuration parameter is set at different levels, this the order of precedence, from highest to lowest, of the table storage values when a user logs into a database and creates a table:

1. The values specified in a `CREATE TABLE` command with the `WITH` clause or `ENCODING` clause
2. The value of `gp_default_storage_options` that set for the user with the `ALTER ROLE...SET` command
3. The value of `gp_default_storage_options` that is set for the database with the `ALTER DATABASE...SET` command
4. The value of `gp_default_storage_options` that is set for the WarehousePG cluster with the `gpconfig` utility

The parameter value is not cumulative. For example, if the parameter specifies the `appendoptimized` and `compresstype` options for a database and a user logs in and sets the parameter to specify the value for the `orientation` option, the `appendoptimized`, and `compresstype` values set at the database level are ignored.

This example `ALTER DATABASE` command sets the default `orientation` and `compresstype` table storage options for the database `mytest`.

```
ALTER DATABASE mytest SET gp_default_storage_options = 'orientation=column, compresstype=rle_type'
```

To create an append-optimized table in the `mytest` database with column-oriented table and RLE compression. The user needs to specify only `appendoptimized=TRUE` in the `WITH` clause.

This example `gpconfig` utility command sets the default storage option for a WarehousePG cluster. If you set the defaults for multiple table storage options, the value must be enclosed in single quotes.

```
gpconfig -c 'gp_default_storage_options' -v 'appendoptimized=true, orientation=column'
```

This example `gpconfig` utility command shows the value of the parameter. The parameter value must be consistent across the WarehousePG coordinator and all segments.

```
gpconfig -s 'gp_default_storage_options'
```

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Value Range	Default	Set Classifications[1]
`appendoptimized` = `TRUE` or `FALSE`	`appendoptimized` = `FALSE`	coordinator, session, reload
`blocksize` = integer between 8192 and 2097152	`blocksize` = `32768`	
`checksum` = `TRUE` or `FALSE`	`checksum` = `TRUE`	
`compresstype` = `ZLIB` or `ZSTD` or `RLE_TYPE` or `NONE`	`compresstype` = `none`	
`compresslevel` = integer between 0 and 19	`compresslevel` = `0`	
`orientation` = `ROW` | `COLUMN`	`orientation` = `ROW`	

Note [1]The set classification when the parameter is set at the system level with the `gpconfig` utility.

gp_dispatch_keepalives_count

Maximum number of TCP keepalive retransmits from a WarehousePG Query Dispatcher to its Query Executors. It controls the number of consecutive keepalive retransmits that can be lost before a connection between a Query Dispatcher and a Query Executor is considered dead.

Value Range	Default	Set Classifications
0 to 127	0 (it uses the system default)	coordinator, system, restart

gp_dispatch_keepalives_idle

Time in seconds between issuing TCP keepalives from a WarehousePG Query Dispatcher to its Query Executors.

Value Range	Default	Set Classifications
0 to 32767	0 (it uses the system default)	coordinator, system, restart

gp_dispatch_keepalives_interval

Time in seconds between TCP keepalive retransmits from a WarehousePG Query Dispatcher to its Query Executors.

Value Range	Default	Set Classifications
0 to 32767	0 (it uses the system default)	coordinator, system, restart

gp_dynamic_partition_pruning

Enables plans that can dynamically eliminate the scanning of partitions.

Value Range	Default	Set Classifications
Boolean	on	coordinator, session, reload

gp_eager_two_phase_agg

Activates or deactivates two-phase aggregation for the Postgres-based planner.

The default value is `off`; the Postgres-based planner chooses the best aggregate path for a query based on the cost. When set to `on`, the Postgres-based planner adds a disable cost to each of the first stage aggregate paths, which in turn forces the Postgres-based planner to generate and choose a multi-stage aggregate path.

Value Range	Default	Set Classifications
Boolean	off	coordinator, session, reload

gp_enable_agg_distinct

Activates or deactivates two-phase aggregation to compute a single distinct-qualified aggregate. This applies only to subqueries that include a single distinct-qualified aggregate function.

Value Range	Default	Set Classifications
Boolean	on	coordinator, session, reload

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gp_enable_agg_distinct_pruning

Activates or deactivates three-phase aggregation and join to compute distinct-qualified aggregates. This applies only to subqueries that include one or more distinct-qualified aggregate functions.

Value Range	Default	Set Classifications
Boolean	on	coordinator, session, reload

gp_enable_direct_dispatch

Activates or deactivates the dispatching of targeted query plans for queries that access data on a single segment. When on, queries that target rows on a single segment will only have their query plan dispatched to that segment (rather than to all segments). This significantly reduces the response time of qualifying queries as there is no interconnect setup involved. Direct dispatch does require more CPU utilization on the coordinator.

Value Range	Default	Set Classifications
Boolean	on	coordinator, session, reload

gp_enable_fast_sri

When set to `on`, the Postgres-based planner plans single row inserts so that they are sent directly to the correct segment instance (no motion operation required). This significantly improves performance of single-row-insert statements.

Value Range	Default	Set Classifications
Boolean	on	coordinator, session, reload

gp_enable_global_deadlock_detector

Controls whether the WarehousePG Global Deadlock Detector is enabled to manage concurrent `UPDATE` and `DELETE` operations on heap tables to improve performance. See DML: Inserting, Updating and Deleting in the *WarehousePG Administrator Guide*. The default is `off`, the Global Deadlock Detector is deactivated.

If the Global Deadlock Detector is deactivated (the default), WarehousePG runs concurrent update and delete operations on a heap table serially.

If the Global Deadlock Detector is enabled, concurrent updates are permitted and the Global Deadlock Detector determines when a deadlock exists, and breaks the deadlock by cancelling one or more backend processes associated with the youngest transaction(s) involved.

Value Range	Default	Set Classifications
Boolean	off	coordinator, system, restart

gp_enable_groupext_distinct_gather

Activates or deactivates gathering data to a single node to compute distinct-qualified aggregates on grouping extension queries. When this parameter and `gp_enable_groupext_distinct_pruning` are both enabled, the Postgres-based planner uses the cheaper plan.

Value Range	Default	Set Classifications
Boolean	on	coordinator, session, reload

gp_enable_groupext_distinct_pruning

Activates or deactivates three-phase aggregation and join to compute distinct-qualified aggregates on grouping extension queries. Usually, enabling this parameter generates a cheaper query plan that the Postgres-based planner will use in preference to existing plan.

Value Range	Default	Set Classifications
Boolean	on	coordinator, session, reload

gp_enable_multiphase_agg

Activates or deactivates the use of two or three-stage parallel aggregation plans Postgres-based planner. This approach applies to any subquery with aggregation. If `gp_enable_multiphase_agg` is off, then `gp_enable_agg_distinct` and `gp_enable_agg_distinct_pruning` are deactivated.

Value Range	Default	Set Classifications
Boolean	on	coordinator, session, reload

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gp_enable_predicate_propagation

When enabled, the Postgres-based planner applies query predicates to both table expressions in cases where the tables are joined on their distribution key column(s). Filtering both tables prior to doing the join (when possible) is more efficient.

Value Range	Default	Set Classifications
Boolean	on	coordinator, session, reload

gp_enable_preunique

Enables two-phase duplicate removal for `SELECT DISTINCT` queries (not `SELECT COUNT(DISTINCT)`). When enabled, it adds an extra `SORT DISTINCT` set of plan nodes before motioning. In cases where the distinct operation greatly reduces the number of rows, this extra `SORT DISTINCT` is much cheaper than the cost of sending the rows across the Interconnect.

Value Range	Default	Set Classifications
Boolean	on	coordinator, session, reload

gp_enable_relsize_collection

Enables GPORCA and the Postgres-based planner to use the estimated size of a table (`pg_relation_size` function) if there are no statistics for the table. By default, GPORCA and the planner use a default value to estimate the number of rows if statistics are not available. The default behavior improves query optimization time and reduces resource queue usage in heavy workloads, but can lead to suboptimal plans.

This parameter is ignored for a root partitioned table. When GPORCA is enabled and the root partition does not have statistics, GPORCA always uses the default value. You can use `ANALZYE ROOTPARTITION` to collect statistics on the root partition. See ANALYZE.

Value Range	Default	Set Classifications
Boolean	off	coordinator, session, reload

gp_enable_segment_copy_checking

Controls whether the distribution policy for a table (from the table `DISTRIBUTED` clause) is checked when data is copied into the table with the `COPY FROM...ON SEGMENT` command. If true, an error is returned if a row of data violates the distribution policy for a segment instance. The default is `true` .

If the value is `false` , the distribution policy is not checked. The data added to the table might violate the table distribution policy for the segment instance. Manual redistribution of table data might be required. See the `ALTER TABLE` clause `WITH REORGANIZE` .

The parameter can be set for a database system or a session. The parameter cannot be set for a specific database.

Value Range	Default	Set Classifications
Boolean	true	coordinator, session, reload

gp_enable_sort_limit

Enable `LIMIT` operation to be performed while sorting. Sorts more efficiently when the plan requires the first *limit_number* of rows at most.

Value Range	Default	Set Classifications
Boolean	on	coordinator, session, reload

gp_external_enable_exec

Activates or deactivates the use of external tables that run OS commands or scripts on the segment hosts (`CREATE EXTERNAL TABLE EXECUTE` syntax).

Value Range	Default	Set Classifications
Boolean	on	coordinator, system, restart

gp_explain_jit

Prints summarized JIT information from all query executions when JIT compilation is enabled.

Value Range	Default	Set Classifications
boolean	on	coordinator, session, reload

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gp_external_max_segs

Sets the number of segments that will scan external table data during an external table operation, the purpose being not to overload the system with scanning data and take away resources from other concurrent operations. This only applies to external tables that use the `gpfdist://` protocol to access external table data.

Value Range	Default	Set Classifications
integer	64	coordinator, session, reload

gp_external_enable_filter_pushdown

Enable filter pushdown when reading data from external tables. If pushdown fails, a query is run without pushing filters to the external data source (instead, WarehousePG applies the same constraints to the result). See Defining External Tables for more information.

Value Range	Default	Set Classifications
Boolean	on	coordinator, session, reload

gp_fts_probe_interval

Specifies the polling interval for the fault detection process (`ftsprobe`). The `ftsprobe` process will take approximately this amount of time to detect a segment failure.

Value Range	Default	Set Classifications
10 - 3600 seconds	1min	coordinator, system, reload

gp_fts_probe_retries

Specifies the number of times the fault detection process (`ftsprobe`) attempts to connect to a segment before reporting segment failure.

Value Range	Default	Set Classifications
integer	5	coordinator, system, reload

gp_fts_probe_timeout

Specifies the allowed timeout for the fault detection process (`ftsprobe`) to establish a connection to a segment before declaring it down.

Value Range	Default	Set Classifications
10 - 3600 seconds	20 secs	coordinator, system, reload

gp_fts_replication_attempt_count

Specifies the maximum number of times that WarehousePG attempts to establish a primary-mirror replication connection. When this count is exceeded, the fault detection process (`ftsprobe`) stops retrying and marks the mirror down.

Value Range	Default	Set Classifications
0 - 100	10	coordinator, system, reload

gp_global_deadlock_detector_period

Specifies the executing interval (in seconds) of the global deadlock detector background worker process.

Value Range	Default	Set Classifications
5 - `INT_MAX` secs	120 secs	coordinator, system, reload

gp_log_endpoints

Controls the amount of parallel retrieve cursor endpoint detail that WarehousePG writes to the server log file.

The default value is `false` , WarehousePG does not log endpoint details to the log file. When set to `true` , WarehousePG writes endpoint detail information to the log file.

Value Range	Default	Set Classifications
Boolean	false	coordinator, session, reload

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gp_log_fts

Controls the amount of detail the fault detection process (`ftsprobe`) writes to the log file.

Value Range	Default	Set Classifications
OFF, TERSE, VERBOSE, DEBUG	TERSE	coordinator, system, restart

gp_log_interconnect

Controls the amount of information that is written to the log file about communication between WarehousePG segment instance worker processes. The default value is `terse` . The log information is written to both the coordinator and segment instance logs.

Increasing the amount of logging could affect performance and increase disk space usage.

Value Range	Default	Set Classifications
off, terse, verbose, debug	terse	coordinator, session, reload

gp_log_gang

Controls the amount of information that is written to the log file about query worker process creation and query management. The default value is `OFF` , do not log information.

Value Range	Default	Set Classifications
OFF, TERSE, VERBOSE, DEBUG	OFF	coordinator, session, restart

gp_hashjoin_tuples_per_bucket

Sets the target density of the hash table used by HashJoin operations. A smaller value will tend to produce larger hash tables, which can increase join performance.

Value Range	Default	Set Classifications
integer	5	coordinator, session, reload

gp_ignore_error_table

Controls WarehousePG behavior when the deprecated `INTO ERROR TABLE` clause is specified in a `CREATE EXTERNAL TABLE` or `COPY` command.

> **Note** The `INTO ERROR TABLE` clause was deprecated and removed in WarehousePG 5. In WarehousePG 7, this parameter will be removed as well, causing all `INTO ERROR TABLE` invocations be yield a syntax error.

The default value is `false` , WarehousePG returns an error if the `INTO ERROR TABLE` clause is specified in a command.

If the value is `true` , WarehousePG ignores the clause, issues a warning, and runs the command without the `INTO ERROR TABLE` clause. In WarehousePG 6.x and later, you access the error log information with built-in SQL functions. See the CREATE EXTERNAL TABLE or COPY command.

You can set this value to `true` to avoid the WarehousePG error when you run applications that run `CREATE EXTERNAL TABLE` or `COPY` commands that include the unsupoorted `INTO ERROR TABLE` clause.

Value Range	Default	Set Classifications
Boolean	false	coordinator, session, reload

gp_initial_bad_row_limit

For the parameter value *n*, WarehousePG stops processing input rows when you import data with the `COPY` command or from an external table if the first *n* rows processed contain formatting errors. If a valid row is processed within the first *n* rows, WarehousePG continues processing input rows.

Setting the value to 0 deactivates this limit.

The `SEGMENT REJECT LIMIT` clause can also be specified for the `COPY` command or the external table definition to limit the number of rejected rows.

`INT_MAX` is the largest value that can be stored as an integer on your system.

Value Range	Default	Set Classifications
integer 0 - `INT_MAX`	1000	coordinator, session, reload

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gp_interconnect_address_type

Specifies the type of address binding strategy WarehousePG uses for communication between segment host sockets. There are two types: `unicast` and `wildcard`. The default is `unicast`.

- When this parameter is set to `unicast`, WarehousePG uses the `gp_segment_configuration.address` field to perform address binding. This reduces port usage on segment hosts and prevents interconnect traffic from being routed through unintended (and possibly slower) network interfaces. This is the recommended option.
- When this parameter is set to `wildcard`, WarehousePG uses a wildcard address for binding, enabling the use of any network interface compliant with routing rules.

> **Note** In some cases, inter-segment communication using the unicast strategy may not be possible. One example is if the source segment's address field and the destination segment's address field are on different subnets and/or existing routing rules do not allow for such communication. In these cases, we recommend you use a single subnet for all segment addresses, or fix routing rules to allow communication between subnets. If neither is possible, you will need to configure this parameter to `wildcard` for wildcard address binding.

Value Range	Default	Set Classifications
wildcard,unicast	unicast	local, system, reload

gp_interconnect_debug_retry_interval

Specifies the interval, in seconds, to log WarehousePG interconnect debugging messages when the server configuration parameter gp_log_interconnect is set to `DEBUG`. The default is 10 seconds.

The log messages contain information about the interconnect communication between WarehousePG segment instance worker processes. The information can be helpful when debugging network issues between segment instances.

Value Range	Default	Set Classifications
1 =< Integer < 4096	10	coordinator, session, reload

gp_interconnect_fc_method

Specifies the flow control method used for the default WarehousePG UDPIFC interconnect.

For capacity based flow control, senders do not send packets when receivers do not have the capacity.

Loss based flow control is based on capacity based flow control, and also tunes the sending speed according to packet losses.

Value Range	Default	Set Classifications
CAPACITY, LOSS	LOSS	coordinator, session, reload

gp_interconnect_proxy_addresses

Sets the proxy ports that WarehousePG uses when the server configuration parameter gp_interconnect_type is set to `proxy`. Otherwise, this parameter is ignored. The default value is an empty string ("").

When the `gp_interconnect_type` parameter is set to `proxy`, You must specify a proxy port for the coordinator, standby coordinator, and all primary and mirror segment instances in this format:

```
<db_id>:<cont_id>:<seg_address>:<port>[, ... ]
```

For the coordinator, standby coordinator, and segment instance, the first three fields, db_id, cont_id, and seg_address can be found in thegp_segment_configuration catalog table. The fourth field, port, is the proxy port for the WarehousePG coordinator or a segment instance.

- db_id is the `dbid` column in the catalog table.
- cont_id is the `content` column in the catalog table.
- seg_address is the IP address or hostname corresponding to tge `address` column in the catalog table.
- port is the TCP/IP port for the segment instance proxy that you specify.

> **Important** If a segment instance hostname is bound to a different IP address at runtime, you must run `gpstop -U` to re-load the `gp_interconnect_proxy_addresses` value.

You must specify the value as a single-quoted string. This `gpconfig` command sets the value for `gp_interconnect_proxy_addresses` as a single-quoted string. The WarehousePG cluster consists of a coordinator and a single segment instance.

```
gpconfig --skipvalidation -c gp_interconnect_proxy_addresses -v "'1:-1:192.168.180.50:35432,2:0:192.168.180.54:35000'"
```

For an example of setting `gp_interconnect_proxy_addresses`, see Configuring Proxies for the WarehousePG Interconnect.

Value Range	Default	Set Classifications
string (maximum length - 16384 bytes)		local, system, reload

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gp_interconnect_queue_depth

Sets the amount of data per-peer to be queued by the WarehousePG interconnect on receivers (when data is received but no space is available to receive it the data will be dropped, and the transmitter will need to resend it) for the default UDPIFC interconnect. Increasing the depth from its default value will cause the system to use more memory, but may increase performance. It is reasonable to set this value between 1 and 10. Queries with data skew potentially perform better with an increased queue depth. Increasing this may radically increase the amount of memory used by the system.

Value Range	Default	Set Classifications
1-2048	4	coordinator, session, reload

gp_interconnect_setup_timeout

Specifies the amount of time, in seconds, that WarehousePG waits for the interconnect to complete setup before it times out.

Value Range	Default	Set Classifications
0 - 7200 seconds	7200 seconds (2 hours)	coordinator, session, reload

gp_interconnect_snd_queue_depth

Sets the amount of data per-peer to be queued by the default UDPIFC interconnect on senders. Increasing the depth from its default value will cause the system to use more memory, but may increase performance. Reasonable values for this parameter are between 1 and 4. Increasing the value might radically increase the amount of memory used by the system.

Value Range	Default	Set Classifications
1 - 4096	2	coordinator, session, reload

gp_interconnect_transmit_timeout

Specifies the amount of time, in seconds, that WarehousePG waits for network transmission of interconnect traffic to complete before it times out.

Value Range	Default	Set Classifications
1 - 7200 seconds	3600 seconds (1 hour)	coordinator, session, reload

gp_interconnect_type

Sets the networking protocol used for WarehousePG interconnect traffic. UDPIFC specifies using UDP with flow control for interconnect traffic, and is the only value supported.

UDPIFC (the default) specifies using UDP with flow control for interconnect traffic. Specify the interconnect flow control method with gp_interconnect_fc_method.

With TCP as the interconnect protocol, WarehousePG has an upper limit of 1000 segment instances - less than that if the query workload involves complex, multi-slice queries.

The `PROXY` value specifies using the TCP protocol, and when running queries, using a proxy for WarehousePG interconnect communication between the coordinator instance and segment instances and between two segment instances. When this parameter is set to `PROXY`, you must specify the proxy ports for the coordinator and segment instances with the server configuration parametergp_interconnect_proxy_addresses. For information about configuring and using proxies with the WarehousePG interconnect, see Configuring Proxies for the WarehousePG Interconnect.

Value Range	Default	Set Classifications
UDPIFC, TCP, PROXY	UDPIFC	local, session, reload

gp_log_format

Specifies the format of the server log files. If using *gp_toolkit* administrative schema, the log files must be in CSV format.

Value Range	Default	Set Classifications
csv, text	csv	local, system, restart

gp_max_local_distributed_cache

Sets the maximum number of distributed transaction log entries to cache in the backend process memory of a segment instance.

The log entries contain information about the state of rows that are being accessed by an SQL statement. The information is used to determine which rows are visible to an SQL transaction when running multiple simultaneous SQL statements in an MVCC environment. Caching distributed transaction log entries locally improves transaction processing speed by improving performance of the row visibility determination process.

The default value is optimal for a wide variety of SQL processing environments.

Value Range	Default	Set Classifications
integer	1024	local, system, restart

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gp_max_packet_size

Sets the tuple-serialization chunk size for the WarehousePG interconnect.

Value Range	Default	Set Classifications
512-65536	8192	coordinator, system, reload

gp_max_parallel_cursors

Specifies the maximum number of active parallel retrieve cursors allowed on a WarehousePG cluster. A parallel retrieve cursor is considered active after it has been `DECLARE`d, but before it is `CLOSE`d or returns an error.

The default value is `-1`; there is no limit on the number of open parallel retrieve cursors that may be concurrently active in the cluster (up to the maximum value of 1024).

Each parallel retrieve cursor creates upto `N` endpoints, where N is the number of primary segments (including the coordinator) in the cluster. On each primary segment, each endpoint costs a small amount of shared memory and consumes one `retrieve` connection that contributes towards the `max_connections` limit.

This GUC is a way to limit that consumption.

You must be a superuser to change the `gp_max_parallel_cursors` setting.

Value Range	Default	Set Classifications
-1 - 1024	-1	coordinator, superuser, session, reload

gp_max_plan_size

Specifies the total maximum uncompressed size of a query execution plan multiplied by the number of Motion operators (slices) in the plan. If the size of the query plan exceeds the value, the query is cancelled and an error is returned. A value of 0 means that the size of the plan is not monitored.

You can specify a value in `kB`, `MB`, or `GB`. The default unit is `kB`. For example, a value of `200` is 200kB. A value of `1GB` is the same as `1024MB` or `1048576kB`.

Value Range	Default	Set Classifications
integer	0	coordinator, superuser, session, reload

gp_max_slices

Specifies the maximum number of slices (portions of a query plan that are run on segment instances) that can be generated by a query. If the query generates more than the specified number of slices, WarehousePG returns an error and does not run the query. The default value is `0`, no maximum value.

Running a query that generates a large number of slices might affect WarehousePG performance. For example, a query that contains `UNION` or `UNION ALL` operators over several complex views can generate a large number of slices. You can run `EXPLAIN ANALYZE` on the query to view slice statistics for the query.

Value Range	Default	Set Classifications
0 - INT_MAX	0	coordinator, session, reload

gp_max_system_slices

> **NOTE** This parameter is identical in behavior to `gp_max_slices`, except that it requires superuser privileges. In addition, it takes precedence over `gp_max_slices` if `gp_max_slices` is greater than its value.

Specifies the maximum number of slices (portions of a query plan that are run on segment instances) that can be generated by a query. If the query generates more than the specified number of slices, WarehousePG returns an error and does not run the query. The default value is `0`, no maximum value.

Running a query that generates a large number of slices might affect WarehousePG performance. For example, a query that contains `UNION` or `UNION ALL` operators over several complex views can generate a large number of slices. You can run `EXPLAIN ANALYZE` on the query to view slice statistics for the query.

Value Range	Default	Set Classifications
0 - INT_MAX	0	coordinator, session, reload, superuser

gp_motion_cost_per_row

Sets the Postgres-based planner cost estimate for a Motion operator to transfer a row from one segment to another, measured as a fraction of the cost of a sequential page fetch. If 0, then the value used is two times the value of *cpu_tuple_cost*.

Value Range	Default	Set Classifications
floating point	0	coordinator, session, reload

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gp_postmaster_address_family

When starting a cluster, this server configuration parameter tells a node which type of IP address to use. When set to `auto`, WarehousePG loops through all the ipv4 and ipv6 addresses specified in `listen_addresses`, trying to open a "listening" port on each one.

Value Range	Default	Set Classifications
auto, ipv4, ipv6	auto	local, system, restart, superuser

gp_print_create_gang_time

When a user starts a session with WarehousePG and issues a query, the system creates groups or 'gangs' of worker processes on each segment to do the work. `gp_print_create_gang_time` controls the display of additional information about gang creation, including gang reuse status and the shortest and longest connection establishment time to the segment.

The default value is `false`, WarehousePG does not display the additional gang creation information.

Value Range	Default	Set Classifications
Boolean	false	coordinator, session, reload

gp_quickz_fallback

Determines how WarehousePG handles legacy SQL that specifies a compression type of QuickLZ, which is not supported in WarehousePG 7 and later. When set to `true`, if legacy SQL specifies a compression type of QuickLZ, WarehousePG will apply a compression type of zstd. When set to `false` -- the default -- specifying a compression type of QuickLZ will result in an error.

Value Range	Default	Set Classifications
Boolean	off	coordinator, session, reload

gp_recursive_cte

Controls the availability of the `RECURSIVE` keyword in the `WITH` clause of a `SELECT [INTO]` command, or a `DELETE`, `INSERT` or `UPDATE` command. The keyword allows a subquery in the `WITH` clause of a command to reference itself. The default value is `true`, the `RECURSIVE` keyword is allowed in the `WITH` clause of a command.

For information about the `RECURSIVE` keyword, see the SELECT command and WITH Queries (Common Table Expressions).

The parameter can be set for a database system, an individual database, or a session or query.

> **Note** This parameter was previously named `gp_recursive_cte_prototype`, but has been renamed to reflect the current status of the implementation.

Value Range	Default	Set Classifications
Boolean	true	coordinator, session, restart

gp_reject_percent_threshold

For single row error handling on COPY and external table SELECTs, sets the number of rows processed before SEGMENT REJECT LIMIT *n* PERCENT starts calculating.

Value Range	Default	Set Classifications
1-*n*	300	coordinator, session, reload

gp_reraise_signal

If enabled, will attempt to dump core if a fatal server error occurs.

Value Range	Default	Set Classifications
Boolean	on	coordinator, session, reload

gp_resgroup_memory_policy

> **Note** The `gp_resgroup_memory_policy` server configuration parameter is enforced only when resource group-based resource management is active.

Used by a resource group to manage memory allocation to query operators.

When set to `auto`, WarehousePG uses resource group memory limits to distribute memory across query operators, allocating a fixed size of memory to non-memory-intensive operators and the rest to memory-intensive operators.

When you specify `eager_free`, WarehousePG distributes memory among operators more optimally by re-allocating memory released by operators that have completed their processing to operators in a later query stage.

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Value Range	Default	Set Classifications
auto, eager_free	eager_free	local, system, superuser, reload

gp_resgroup_memory_query_fixed_mem

> **Note** The `gp_resgroup_memory_query_fixed_mem` server configuration parameter is enforced only when resource group-based resource management is active.

Specifies a fixed amount of memory, in MB, reserved for all queries in a resource group **for the scope of a session**. When this parameter is set to `0`, the default, the `MEMORY_QUOTA` resource group attribute determines this instead.

While `MEMORY_QUOTA` applies to queries across sessions, `gp_resgroup_memory_query_fixed_mem` overrides that limit at a session level. Thus, you can use this configuration parameter to adjust query memory budget for a particular session, on an ad hoc basis.

The value of `gp_resgroup_memory_query_fixed_mem` must be lower than `max_statement_mem`.

Value Range	Default	Set Classifications
0 < integer < INT_MAX	0	coordinator, session, user

gp_resource_group_bypass

> **Note** The `gp_resource_group_bypass` server configuration parameter is enforced only when resource group-based resource management is active.

Activates or deactivates the enforcement of resource group concurrent transaction limits on WarehousePG resources. The default value is `false`, which enforces resource group transaction limits. Resource groups manage resources such as CPU, memory, and the number of concurrent transactions that are used by queries.

You can set this parameter to `true` to bypass resource group concurrent transaction limitations so that a query can run immediately. If you set this parameter to true, the query no longer enforces the CPU or memory limits assigned to its resource group. Instead, the memory quota assigned to this query is `statement_mem` per query. If there is not enough memory to satisfy the memory allocation request, the query will fail.

This parameter can be set for a session. The parameter cannot be set within a transaction or a function.

Value Range	Default	Set Classifications
Boolean	false	local, session, reload

gp_resource_group_bypass_catalog_query

> **Note** The `gp_resource_group_bypass_catalog_query` server configuration parameter is enforced only when resource group-based resource management is active.

When set to `true` -- the default -- WarehousePG's resource group scheduler bypasses all queries that fulfill both of the following criteria:

- They read exclusively from system catalogs
- They contain in their query text `pg_catalog` schema tables only

> **Note** If a query contains a mix of `pg_catalog` and any other schema tables the scheduler will **not** bypass the query.

When this configuration parameter is set to `false` and the database has reached the maximum amount of concurrent transactions, the scheduler can block queries that exclusively read from system catalogs.

Value Range	Default	Set Classifications
Boolean	true	local, session, reload

gp_resource_group_bypass_direct_dispatch

> **Note** The `gp_resource_group_bypass_direct_dispatch` server configuration parameter is enforced only when resource group-based resource management is active.

When set to `true` (the default) WarehousePG's resource group scheduler bypasses the resource group's limits for a direct dispatch query so it can run immediately. A direct dispatch query is a special type of query that only requires a single segment to participate in the execution. In order to improve efficiency, WarehousePG optimizes this type of query, called Direct Dispatch optimization. The system sends the query plan to the execution of a single segment that needs to execute the plan, instead of sending it to all segments for execution. The query uses resources outside the resource groups to allocate memory. If there is not enough memory to satisfy the memory allocation request, the query will fail. You may only set this parameter for a single session, not within a transaction or a function.

Value Range	Default	Set Classifications
Boolean	true	local, session, reload

gp_resource_group_cgroup_parent

> **Note** The `gp_resource_group_cgroup_parent` server configuration parameter is enforced only when resource group-based resource management is active and cgroup v2 is used.

Identifies the root path of the `gpdb` cgroup hierarchy.

Value Range	Default	Set Classifications

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Value Range	Default	Set Classifications
char	"gpdb.service"	local, system, restart, superuser

gp_resource_group_cpu_limit

> **Note** The `gp_resource_group_cpu_limit` server configuration parameter is enforced only when resource group-based resource management is active.

Identifies the maximum percentage of system CPU resources to allocate to resource groups on each WarehousePG segment node.

Value Range	Default	Set Classifications
0.1 - 1.0	0.9	local, system, restart

gp_resource_group_cpu_priority

Sets the CPU priority for WarehousePG processes relative to non-WarehousePG processes when resource groups are enabled. For example, setting this parameter to `10` sets the ratio of allotted CPU resources for WarehousePG processes to non-WarehousePG processes to 10:1.

> **Note** This ratio calculation applies only when the machine's CPU usage is at 100%.

Value Range	Default	Set Classifications
1 - 50	10	local, system, restart

gp_resource_group_move_timeout

> **Note** The `gp_resource_group_move_timeout` server configuration parameter is enforced only when resource group-based resource management is active.

Cancels the `pg_resgroup_move_query()` function, which moves a running query from one resouce group to another, if it waits longer than the specified number of miliseconds.

Value Range	Default	Set Classifications
10 - `INT_MAX` millisecs	3000 millisecs	coordinator, session, reload

gp_resource_group_queuing_timeout

> **Note** The `gp_resource_group_queuing_timeout` server configuration parameter is enforced only when resource group-based resource management is active.

Cancels a transaction queued in a resource group that waits longer than the specified number of milliseconds. The time limit applies separately to each transaction. The default value is zero; transactions are queued indefinitely and never time out.

Value Range	Default	Set Classifications
0 - `INT_MAX` millisecs	0 millisecs	coordinator, session, reload

gp_resource_manager

Identifies the resource management scheme currently enabled in the WarehousePG cluster. For information about WarehousePG resource management, seeManaging Resources.

- `none` - configures WarehousePG to not use any resource manager. This is the default.
- `group` - configures WarehousePG to use resource groups and base resource group behavior on the cgroup v1 version of Linux cgroup functionality.
- `group-v2` - configures WarehousePG to use resource groups and base resource group behavior on the cgroup v2 version of Linux cgroup functionality.
- `queue` - configures WarehousePG to use resource queues.

Value Range	Default	Set Classifications
none, group, group-v2, queue	none	local, system, restart

gp_resqueue_memory_policy

> **Note** The `gp_resqueue_memory_policy` server configuration parameter is enforced only when resource queue-based resource management is active.

Enables WarehousePG memory management features. The distribution algorithm `eager_free` takes advantage of the fact that not all operators run at the same time(in WarehousePG 4.2 and later). The query plan is divided into stages and WarehousePG eagerly frees memory allocated to a previous stage at the end of that stage's execution, then allocates the eagerly freed memory to the new stage.

When set to `none`, memory management is the same as in WarehousePG releases prior to 4.1.

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When set to `auto`, query memory usage is controlled by statement_mem and resource queue memory limits.

Value Range	Default	Set Classifications
none, auto, eager_free	eager_free	local, system, restart/reload

gp_resqueue_priority

> **Note** The `gp_resqueue_priority` server configuration parameter is enforced only when resource queue-based resource management is active.

Activates or deactivates query prioritization. When this parameter is deactivated, existing priority settings are not evaluated at query run time.

Value Range	Default	Set Classifications
Boolean	on	local, system, restart

gp_resqueue_priority_cpucores_per_segment

> **Note** The `gp_resqueue_priority_cpucores_per_segment` server configuration parameter is enforced only when resource queue-based resource management is active.

Specifies the number of CPU units allocated to each segment instance on a segment host. If the segment is configured with primary-mirror segment instance pairs, use the number of primary segment instances on the host in the calculation. Include any CPU core that is available to the operating system, including virtual CPU cores, in the total number of available cores.

For example, if a WarehousePG cluster has 10-core segment hosts that are configured with four primary segments, set the value to 2.5 on each segment host (10 divided by 4). A coordinator host typically has only a single running coordinator instance, so set the value on the coordinator and standby maaster hosts to reflect the usage of all available CPU cores, in this case 10.

Incorrect settings can result in CPU under-utilization or query prioritization not working as designed.

Value Range	Default	Set Classifications
0.1 - 512.0	4	local, system, restart

gp_resqueue_priority_sweeper_interval

> **Note** The `gp_resqueue_priority_sweeper_interval` server configuration parameter is enforced only when resource queue-based resource management is active.

Specifies the interval at which the sweeper process evaluates current CPU usage. When a new statement becomes active, its priority is evaluated and its CPU share determined when the next interval is reached.

Value Range	Default	Set Classifications
500 - 15000 ms	1000	local, system, restart

gp_retrieve_conn

A session that you initiate with `PGOPTIONS='-c gp_retrieve_conn=true'` is a retrieve session. You use a retrieve session to retrieve query result tuples from a specific endpoint instantiated for a parallel retrieve cursor.

The default value is `false`.

Value Range	Default	Set Classifications
Boolean	false	read only

gp_role

The role of this server process is set to *dispatch* for the coordinator and *execute* for a segment.

Value Range	Default	Set Classifications
dispatchexecute, utility		read only

gp_segment_connect_timeout

Time that the WarehousePG interconnect will try to connect to a segment instance over the network before timing out. Controls the network connection timeout between coordinator and primary segments, and primary to mirror segment replication processes.

Value Range	Default	Set Classifications
Any valid time expression (number and unit)	3min	local, session, reload

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gp_segments_for_planner

Sets the number of primary segment instances for the Postgres-based planner to assume in its cost and size estimates. If 0, then the value used is the actual number of primary segments. This variable affects the Postgres-based planner's estimates of the number of rows handled by each sending and receiving process in Motion operators.

Value Range	Default	Set Classifications
0-*n*	0	coordinator, session, reload

gp_server_version

Reports the version number of the server as a string. A version modifier argument might be appended to the numeric portion of the version string, example: *5.0.0 beta*.

Value Range	Default	Set Classifications
String. Examples: *5.0.0*	n/a	read only

gp_server_version_num

Reports the version number of the server as an integer. The number is guaranteed to always be increasing for each version and can be used for numeric comparisons. The major version is represented as is, the minor and patch versions are zero-padded to always be double digit wide.

Value Range	Default	Set Classifications
Mmmpp where *M* is the major version, *mm* is the minor version zero-padded and *pp* is the patch version zero-padded. Example: 50000	n/a	read only

gp_session_id

A system assigned ID number for a client session. Starts counting from 1 when the coordinator instance is first started.

Value Range	Default	Set Classifications
1-*n*	14	read only

gp_set_proc_affinity

If enabled, when a WarehousePG server process (postmaster) is started it will bind to a CPU.

Value Range	Default	Set Classifications
Boolean	off	coordinator, system, restart

gp_set_read_only

Set to on to deactivate writes to the database. Any in progress transactions must finish before read-only mode takes affect.

Value Range	Default	Set Classifications
Boolean	off	coordinator, system, restart

gp_statistics_pullup_from_child_partition

This parameter directs the Postgres-based planner on where to obtain statistics when it plans a query on a partitioned table.

The default value is `off`, the Postgres-based planner uses the statistics of the root partitioned table, if it has any, when it plans a query. If the root partitioned table has no statistics, the Postgres-based planner attempts to use the statistics from the largest child partition.

When set to `on`, the Postgres-based planner attempts to use the statistics from the largest child partition when it plans a query on a partitioned table.

Value Range	Default	Set Classifications
Boolean	off	coordinator, session, reload

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gp_statistics_use_fkeys

When enabled, the Postgres-based planner will use the statistics of the referenced column in the parent table when a column is foreign key reference to another table instead of the statistics of the column itself.

> **Note** This parameter is deprecated and will be removed in a future WarehousePG release.

Value Range	Default	Set Classifications
Boolean	off	coordinator, session, reload

gp_use_legacy_hashops

For a table that is defined with a `DISTRIBUTED BY key\_column` clause, this parameter controls the hash algorithm that is used to distribute table data among segment instances. The default value is `false`, use the jump consistent hash algorithm.

Setting the value to `true` uses the modulo hash algorithm.

Value Range	Default	Set Classifications
Boolean	false	coordinator, session, reload

gp_vmem_idle_resource_timeout

If a database session is idle for longer than the time specified, the session will free system resources (such as shared memory), but remain connected to the database. This allows more concurrent connections to the database at one time.

Value Range	Default	Set Classifications
Any valid time expression (number and unit)	18s	coordinator, session, reload

gp_vmem_protect_limit

When resource queue-based or resource-group based resource management is active, the parameter sets the amount of memory (in number of MBs) that all `postgres` processes of an active segment instance can consume. If a query causes this limit to be exceeded, memory will not be allocated and the query will fail. Note that this is a local parameter and must be set for every segment in the system (primary and mirrors). When setting the parameter value, specify only the numeric value. For example, to specify 4096MB, use the value `4096`. Do not add the units `MB` to the value.

To prevent over-allocation of memory, these calculations can estimate a safe `gp_vmem_protect_limit` value.

First calculate the value of `gp_vmem`. This is the WarehousePG memory available on a host.

- If the total system memory is less than 256 GB, use this formula:

```
gp_vmem = ((SWAP + RAM) – (7.5GB + 0.05 * RAM)) / 1.7
```

- If the total system memory is equal to or greater than 256 GB, use this formula:

```
gp_vmem = ((SWAP + RAM) – (7.5GB + 0.05 * RAM)) / 1.17
```

where SWAP is the host swap space and RAM is the RAM on the host in GB.

Next, calculate the `max_acting_primary_segments`. This is the maximum number of primary segments that can be running on a host when mirror segments are activated due to a failure. With mirrors arranged in a 4-host block with 8 primary segments per host, for example, a single segment host failure would activate two or three mirror segments on each remaining host in the failed host's block. The `max_acting_primary_segments` value for this configuration is 11 (8 primary segments plus 3 mirrors activated on failure).

This is the calculation for `gp_vmem_protect_limit`. The value should be converted to MB.

```
gp_vmem_protect_limit = <gp_vmem> / <acting_primary_segments>
```

For scenarios where a large number of workfiles are generated, this is the calculation for `gp_vmem` that accounts for the workfiles.

- If the total system memory is less than 256 GB:

```
<gp_vmem> = ((<SWAP> + <RAM>) – (7.5GB + 0.05 * <RAM> – (300KB * <total_#_workfiles>))) / 1.7
```

- If the total system memory is equal to or greater than 256 GB:

```
<gp_vmem> = ((<SWAP> + <RAM>) – (7.5GB + 0.05 * <RAM> – (300KB * <total_#_workfiles>))) / 1.17
```

For information about monitoring and managing workfile usage, see the *WarehousePG Administrator Guide*.

Based on the `gp_vmem` value you can calculate the value for the `vm.overcommit_ratio` operating system kernel parameter. This parameter is set when you configure each WarehousePG host.

```
vm.overcommit_ratio = (<RAM> – (0.026 * <gp_vmem>)) / <RAM>
```

> **Note** The default value for the kernel parameter `vm.overcommit_ratio` in Red Hat Enterprise Linux is 50.

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For information about the kernel parameter, see the *WarehousePG Installation Guide*.

Value Range	Default	Set Classifications
integer	8192	local, system, restart

gp_vmem_protect_segworker_cache_limit

If a query executor process consumes more than this configured amount, then the process will not be cached for use in subsequent queries after the process completes. Systems with lots of connections or idle processes may want to reduce this number to free more memory on the segments. Note that this is a local parameter and must be set for every segment.

Value Range	Default	Set Classifications
number of megabytes	500	local, system, restart

gp_workfile_compression

Specifies whether the temporary files created, when a hash aggregation or hash join operation spills to disk, are compressed.

If your WarehousePG installation uses serial ATA (SATA) disk drives, enabling compression might help to avoid overloading the disk subsystem with IO operations.

Value Range	Default	Set Classifications
Boolean	off	coordinator, session, reload

gp_workfile_limit_files_per_query

Sets the maximum number of temporary spill files (also known as workfiles) allowed per query per segment. Spill files are created when running a query that requires more memory than it is allocated. The current query is terminated when the limit is exceeded.

Set the value to 0 (zero) to allow an unlimited number of spill files. coordinator session reload

Value Range	Default	Set Classifications
integer	100000	coordinator, session, reload

gp_workfile_limit_per_query

Sets the maximum disk size an individual query is allowed to use for creating temporary spill files at each segment. The default value is 0, which means a limit is not enforced.

Value Range	Default	Set Classifications
kilobytes	0	coordinator, session, reload

gp_workfile_limit_per_segment

Sets the maximum total disk size that all running queries are allowed to use for creating temporary spill files at each segment. The default value is 0, which means a limit is not enforced.

Value Range	Default	Set Classifications
kilobytes	0	local, system, restart

gpfdist_retry_timeout

Controls the time (in seconds) that WarehousePG waits before returning an error when WarehousePG is attempting to connect or write to a`gpfdist` server and `gpfdist` does not respond. The default value is 300 (5 minutes). A value of 0 deactivates the timeout.

Value Range	Default	Set Classifications
0 - `INT_MAX` (2147483647)	300	local, session, reload

ignore_checksum_failure

Only has effect if data_checksums is enabled.

WarehousePG uses checksums to prevent loading data that has been corrupted in the file system into memory managed by database processes.

By default, when a checksum verify error occurs when reading a heap data page, WarehousePG generates an error and prevents the page from being loaded into managed memory. When `ignore_checksum_failure` is set to on and a checksum verify failure occurs, WarehousePG generates a warning, and allows the page to be read into managed memory. If the page is then updated it is saved to disk and replicated to the mirror. If the page header is corrupt an error is reported even if this option is enabled.

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> **Caution** Setting `ignore_checksum_failure` to on may propagate or hide data corruption or lead to other serious problems. However, if a checksum failure has already been detected and the page header is uncorrupted, setting `ignore_checksum_failure` to on may allow you to bypass the error and recover undamaged tuples that may still be present in the table.

The default setting is off, and it can only be changed by a superuser.

Value Range	Default	Set Classifications
Boolean	off	local, session, reload

integer_datetimes

Reports whether PostgreSQL was built with support for 64-bit-integer dates and times.

Value Range	Default	Set Classifications
Boolean	on	read only

IntervalStyle

Sets the display format for interval values. The value *sql_standard* produces output matching SQL standard interval literals. The value *postgres* produces output matching PostgreSQL releases prior to 8.4 when the DateStyle parameter was set to ISO.

The value *postgres_verbose* produces output matching WarehousePG releases prior to 3.3 when the DateStyle parameter was set to non-ISO output.

The value *iso_8601* will produce output matching the time interval *format with designators* defined in section 4.4.3.2 of ISO 8601. See the PostgreSQL 9.4 documentation for more information.

Value Range	Default	Set Classifications
postgres, postgres_verbose, sql_standard, iso_8601	postgres	coordinator, session, reload

jit

Determines whether JIT compilation may be used by WarehousePG. It enables or disables JIT for both GPORCA and Postgres-based planner.

Value Range	Default	Set Classifications
boolean	off	coordinator, session, reload

jit_above_cost

When using Postgres-based planner, sets the query cost above which JIT compilation is activated when JIT is enabled. Performing JIT compilation costs planning time but can accelerate query execution. Note that setting the JIT cost parameters to '0' forces all queries to be JIT-compiled and, as a result, slows down queries. Setting it to a negative value disables JIT compilation.

Value Range	Default	Set Classifications
floating point	100000	coordinator, session, reload

jit_debugging_support

If LLVM has the required functionality, register generated functions with GDB. This makes debugging easier. The default setting is `off`. This parameter can only be set at server start or when a client connection starts (for example using `PGOPTIONS`).

Value Range	Default	Set Classifications
boolean	off	coordinator, session, reload, superuser

jit_dump_bitcode

Writes the generated LLVM IR out to the file system, inside data_directory. This is only useful for working on the internals of the JIT implementation. The default setting is `off`. Only superusers and users with the appropriate `SET` privilege can change this setting.

Value Range	Default	Set Classifications
boolean	off	coordinator, session, reload

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jit_expressions

Allows JIT compilation of expressions, when JIT compilation is activated.

Value Range	Default	Set Classifications
boolean	on	coordinator, session, reload

jit_inline_above_cost

When using Postgres-based planner, sets the query cost above which JIT compilation attempts to inline functions and operators. Inlining adds planning time, but can improve execution speed. It is not meaningful to set this to less than `jit_above_cost`. Note that setting the JIT cost parameters to '0' forces all queries to be JIT-compiled and, as a result, slows down queries. Setting it to a negative value disables inlining.

Value Range	Default	Set Classifications
floating point	500000	coordinator, session, reload

jit_optimize_above_cost

When using Postgres-based planner, sets the query cost above which JIT compilation applies expensive optimizations. Such optimization adds planning time, but can improve execution speed. It is not meaningful to set this to less than `jit_above_cost`, and it is unlikely to be beneficial to set it to more than `jit_inline_above_cost`. Note that setting the JIT cost parameters to '0' forces all queries to be JIT-compiled and, as a result, slows down queries. Setting it to a negative value disables expensive optimizations.

Value Range	Default	Set Classifications
floating point	500000	coordinator, session, reload

jit_profiling_support

If LLVM has the required functionality, emit the data needed to allow `perf` command to profile functions generated by JIT. This writes out files to `~/.debug/jit/`. If you have set and loaded the environment variable `JITDUMPDIR`, it will write to `JITDUMPDIR/debug/jit` instead. You are responsible for performing cleanup when desired. The default setting is `off`. This parameter can only be set at server start or when a client connection starts (for example using `PGOPTIONS`).

Value Range	Default	Set Classifications
boolean	off	coordinator, session, reload, superuser

jit_provider

Indicates the name of the JIT provider (library of JIT driver) to load. The default is `llvmjit`, any other value is not officially supported. This parameter can only be set at server start.

Value Range	Default	Set Classifications
string	llvmjit	local, session, restart, superuser

jit_tuple_deforming

Allows JIT compilation of tuple deforming, when JIT compilation is activated.

Value Range	Default	Set Classifications
boolean	on	coordinator, session, reload

join_collapse_limit

The Postgres-based planner will rewrite explicit inner `JOIN` constructs into lists of `FROM` items whenever a list of no more than this many items in total would result. By default, this variable is set the same as *from_collapse_limit*, which is appropriate for most uses. Setting it to 1 prevents any reordering of inner JOINs. Setting this variable to a value between 1 and *from_collapse_limit* might be useful to trade off planning time against the quality of the chosen plan (higher values produce better plans).

Value Range	Default	Set Classifications
1-*n*	20	coordinator, session, reload

krb_caseins_users

Sets whether Kerberos user names should be treated case-insensitively. The default is case sensitive (off).

Value Range	Default	Set Classifications
Boolean	off	coordinator, system, reload

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krb_server_keyfile

Sets the location of the Kerberos server key file.

Value Range	Default	Set Classifications
path and file name	unset	coordinator, system, restart

lc_collate

Reports the locale in which sorting of textual data is done. The value is determined when the WarehousePG cluster is initialized.

Value Range	Default	Set Classifications
<system dependent>		read only

lc_ctype

Reports the locale that determines character classifications. The value is determined when the WarehousePG cluster is initialized.

Value Range	Default	Set Classifications
<system dependent>		read only

lc_messages

Sets the language in which messages are displayed. The locales available depends on what was installed with your operating system - use *locale -a* to list available locales. The default value is inherited from the execution environment of the server. On some systems, this locale category does not exist. Setting this variable will still work, but there will be no effect. Also, there is a chance that no translated messages for the desired language exist. In that case you will continue to see the English messages.

Value Range	Default	Set Classifications
<system dependent>		local, session, reload

lc_monetary

Sets the locale to use for formatting monetary amounts, for example with the *to_char* family of functions. The locales available depends on what was installed with your operating system - use *locale -a* to list available locales. The default value is inherited from the execution environment of the server.

Value Range	Default	Set Classifications
<system dependent>		local, session, reload

lc_numeric

Sets the locale to use for formatting numbers, for example with the *to_char* family of functions. The locales available depends on what was installed with your operating system - use *locale -a* to list available locales. The default value is inherited from the execution environment of the server.

Value Range	Default	Set Classifications
<system dependent>		local, system, restart

lc_time

This parameter currently does nothing, but may in the future.

Value Range	Default	Set Classifications
<system dependent>		local, system, restart

listen_addresses

Specifies the TCP/IP address(es) on which the server is to listen for connections from client applications - a comma-separated list of host names and/or numeric IP addresses. The special entry * corresponds to all available IP interfaces. If the list is empty, only UNIX-domain sockets can connect.

Value Range	Default	Set Classifications
localhost, host names, IP addresses, * (all available IP interfaces)	*	coordinator, system, restart

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local_preload_libraries

Comma separated list of shared library files to preload at the start of a client session.

Value Range	Default	Set Classifications
		local, system, restart

lock_timeout

Abort any statement that waits longer than the specified number of milliseconds while attempting to acquire a lock on a table, index, row, or other database object. The time limit applies separately to each lock acquisition attempt. The limit applies both to explicit locking requests (such as `LOCK TABLE`, or `SELECT FOR UPDATE` without `NOWAIT`) and to implicitly-acquired locks. If `log_min_error_statement` is set to `ERROR` or lower, WarehousePG logs the statement that timed out. A value of zero (the default) turns off this lock wait monitoring.

Unlike statement_timeout, this timeout can only occur while waiting for locks. Note that if `statement_timeout` is nonzero, it is rather pointless to set `lock_timeout` to the same or larger value, since the statement timeout would always trigger first.

WarehousePG uses the deadlock_timeout and gp_global_deadlock_detector_period to trigger local and global deadlock detection. Note that if `lock_timeout` is turned on and set to a value smaller than these deadlock detection timeouts, WarehousePG will abort a statement before it would ever trigger a deadlock check in that session.

> **Note** Setting `lock_timeout` in `postgresql.conf` is not recommended because it would affect all sessions

Value Range	Default	Set Classifications
0 - `INT_MAX` millisecs	0 millisecs	coordinator, session, reload

log_autostats

Logs information about automatic `ANALYZE` operations related to gp_autostats_modeand gp_autostats_on_change_threshold.

Value Range	Default	Set Classifications
Boolean	off	coordinator, session, reload, superuser

log_connections

This outputs a line to the server log detailing each successful connection. Some client programs, like psql, attempt to connect twice while determining if a password is required, so duplicate "connection received" messages do not always indicate a problem.

Value Range	Default	Set Classifications
Boolean	off	local, system, reload

log_checkpoints

Causes checkpoints and restartpoints to be logged in the server log. Some statistics are included in the log messages, including the number of buffers written and the time spent writing them.

Value Range	Default	Set Classifications
Boolean	on	local, system, reload

log_directory

Sets the destination directory for log files. You may specify its value as relative to the coordinator and segments data directory or as absolute path. Only superusers and users privilege can change this setting. The default value, `log`, indicates that the logs are located in the `log` directory under the coordinator and segment data directory.

When you specify the value as an absolute path, or as a relative path that is outside the data directory, WarehousePG appends a subdirectory with a unique identifier (DBID) to the directory specified by this parameter. The unique identifier matches the value of `dbid` from `gp_segment_configuration`. For example, if you set `log_directory` as `/tmp/logs`, WarehousePG creates the directories: `/tmp/logs/1` for the coordinator, `/tmp/logs/2` for seg0, `/tmp/logs/3` for seg1, etcetera.

> **Important** Do not remove the default log directories as some WarehousePG utilities will still need them during initialization.

Value Range	Default	Set Classifications
String	log	coordinator, system, reload, superuser

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log_disconnections

This outputs a line in the server log at termination of a client session, and includes the duration of the session.

Value Range	Default	Set Classifications
Boolean	off	local, system, reload

log_dispatch_stats

When set to "on," this parameter adds a log message with verbose information about the dispatch of the statement.

Value Range	Default	Set Classifications
Boolean	off	local, system, reload

log_duration

Causes the duration of every completed statement which satisfies *log_statement* to be logged.

Value Range	Default	Set Classifications
Boolean	off	coordinator, session, reload, superuser

log_error_verbosity

Controls the amount of detail written in the server log for each message that is logged.

Value Range	Default	Set Classifications
TERSE, DEFAULT, VERBOSE	DEFAULT	coordinator, session, reload, superuser

log_executor_stats

For each query, write performance statistics of the query executor to the server log. This is a crude profiling instrument. Cannot be enabled together with*log_statement_stats*.

Value Range	Default	Set Classifications
Boolean	off	local, system, restart

log_file_mode

On Unix systems this parameter sets the permissions for log files when `logging_collector` is enabled. The parameter value is expected to be a numeric mode specified in the format accepted by the `chmod` and `umask` system calls.

Value Range	Default	Set Classifications
numeric UNIX file permission mode (as accepted by the *chmod* or *umask* commands)	0600	local, system, reload

log_hostname

By default, connection log messages only show the IP address of the connecting host. Turning on this option causes logging of the IP address and host name of the WarehousePG coordinator. Note that depending on your host name resolution setup this might impose a non-negligible performance penalty.

Value Range	Default	Set Classifications
Boolean	off	coordinator, system, reload

log_min_duration_statement

Logs the statement and its duration on a single log line if its duration is greater than or equal to the specified number of milliseconds. Setting this to 0 will print all statements and their durations. -1 deactivates the feature. For example, if you set it to 250 then all SQL statements that run 250ms or longer will be logged. Enabling this option can be useful in tracking down unoptimized queries in your applications.

Value Range	Default	Set Classifications
number of milliseconds, 0, -1	-1	coordinator, session, reload, superuser

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log_min_error_statement

Controls whether or not the SQL statement that causes an error condition will also be recorded in the server log. All SQL statements that cause an error of the specified level or higher are logged. The default is ERROR. To effectively turn off logging of failing statements, set this parameter to PANIC.

Value Range	Default	Set Classifications
DEBUG5, DEBUG4, DEBUG3, DEBUG2, DEBUG1, INFO, NOTICE, WARNING, ERROR, FATAL, PANIC	ERROR	coordinator, session, reload, superuser

log_min_messages

Controls which message levels are written to the server log. Each level includes all the levels that follow it. The later the level, the fewer messages are sent to the log.

Value Range	Default	Set Classifications
DEBUG5, DEBUG4, DEBUG3, DEBUG2, DEBUG1, INFO, NOTICE, WARNING, LOG, ERROR, FATAL, PANIC	WARNING	coordinator, session, reload, superuser

log_parser_stats

For each query, write performance statistics of the query parser to the server log. This is a crude profiling instrument. Cannot be enabled together with *log_statement_stats*.

Value Range	Default	Set Classifications
Boolean	off	coordinator, session, reload, superuser

log_planner_stats

For each query, write performance statistics of the Postgres-based planner to the server log. This is a crude profiling instrument. Cannot be enabled together with *log_statement_stats*.

Value Range	Default	Set Classifications
Boolean	off	coordinator, session, reload, superuser

log_rotation_age

Determines the amount of time WarehousePG writes messages to the active log file. When this amount of time has elapsed, the file is closed and a new log file is created. Set to zero to deactivate time-based creation of new log files.

Value Range	Default	Set Classifications
Any valid time expression (number and unit)	1d	local, system, restart

log_rotation_size

Determines the size of an individual log file that triggers rotation. When the log file size is equal to or greater than this size, the file is closed and a new log file is created. Set to zero to deactivate size-based creation of new log files.

The maximum value is INT_MAX/1024. If an invalid value is specified, the default value is used. INT_MAX is the largest value that can be stored as an integer on your system.

Value Range	Default	Set Classifications
number of kilobytes	1048576	local, system, restart

log_statement

Controls which SQL statements are logged. DDL logs all data definition commands like CREATE, ALTER, and DROP commands. MOD logs all DDL statements, plus INSERT, UPDATE, DELETE, TRUNCATE, and COPY FROM. PREPARE and EXPLAIN ANALYZE statements are also logged if their contained command is of an appropriate type.

Value Range	Default	Set Classifications
NONE, DDL, MOD, ALL	ALL	coordinator, session, reload, superuser

log_statement_stats

For each query, write total performance statistics of the query parser, planner, and executor to the server log. This is a crude profiling instrument.

Value Range	Default	Set Classifications
Boolean	off	coordinator, session, reload, superuser

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log_temp_files

Controls logging of temporary file names and sizes. Temporary files can be created for sorts, hashes, temporary query results and spill files. A log entry is made in `log` for each temporary file when it is deleted. Depending on the source of the temporary files, the log entry could be created on either the coordinator and/or segments. A `log_temp_files` value of zero logs all temporary file information, while positive values log only files whose size is greater than or equal to the specified number of kilobytes. The default setting is `-1`, which deactivates logging. Only superusers can change this setting.

Value Range	Default	Set Classifications
Integer	-1	local, session, reload

log_timezone

Sets the time zone used for timestamps written in the log. UnlikeTimeZone, this value is system-wide, so that all sessions will report timestamps consistently. The default is `unknown`, which means to use whatever the system environment specifies as the time zone.

Value Range	Default	Set Classifications
string	unknown	local, system, restart

log_truncate_on_rotation

Truncates (overwrites), rather than appends to, any existing log file of the same name. Truncation will occur only when a new file is being opened due to time-based rotation. For example, using this setting in combination with a log_filename such as `gpseg#-%H.log` would result in generating twenty-four hourly log files and then cyclically overwriting them. When off, pre-existing files will be appended to in all cases.

Value Range	Default	Set Classifications
Boolean	off	local, system, reload

maintenance_work_mem

Specifies the maximum amount of memory to be used in maintenance operations, such as `VACUUM` and `CREATE INDEX`. It defaults to 16 megabytes (16MB). Larger settings might improve performance for vacuuming and for restoring database dumps.

Value Range	Default	Set Classifications
Integer	16	local, system, reload

max_connections

The maximum number of concurrent connections to the database server. In a WarehousePG cluster, user client connections go through the WarehousePG coordinator instance only. Segment instances should allow 3-10 times the amount as the coordinator. When you increase this parameter, max_prepared_transactions must be increased as well. For more information about limiting concurrent connections, see "Configuring Client Authentication" in the *WarehousePG Administrator Guide*.

Increasing this parameter may cause WarehousePG to request more shared memory. See shared_buffers for information about WarehousePG server instance shared memory buffers.

Value Range	Default	Set Classifications
10 - 262143	250 on coordinator750 on segments	

|local, system, restart|

max_files_per_process

Sets the maximum number of simultaneously open files allowed to each server subprocess. If the kernel is enforcing a safe per-process limit, you don't need to worry about this setting. Some platforms such as BSD, the kernel will allow individual processes to open many more files than the system can really support.

Value Range	Default	Set Classifications
integer	1000	local, system, restart

max_function_args

Reports the maximum number of function arguments.

Value Range	Default	Set Classifications
integer	100	read only

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max_identifier_length

Reports the maximum identifier length.

Value Range	Default	Set Classifications
integer	63	read only

max_index_keys

Reports the maximum number of index keys.

Value Range	Default	Set Classifications
integer	32	read only

max_locks_per_transaction

The shared lock table is created with room to describe locks on *max_locks_per_transaction* * (*max_connections* + *max_prepared_transactions*) objects, so no more than this many distinct objects can be locked at any one time. This is not a hard limit on the number of locks taken by any one transaction, but rather a maximum average value. You might need to raise this value if you have clients that touch many different tables in a single transaction.

Value Range	Default	Set Classifications
integer	128	local, system, restart

max_prepared_transactions

Sets the maximum number of transactions that can be in the prepared state simultaneously. WarehousePG uses prepared transactions internally to ensure data integrity across the segments. This value must be at least as large as the value of max_connections on the coordinator. Segment instances should be set to the same value as the coordinator.

Value Range	Default	Set Classifications
integer	250 on coordinator, 250 on segments	local, system, restart

max_resource_portals_per_transaction

> **Note** The `max_resource_portals_per_transaction` server configuration parameter is enforced only when resource queue-based resource management is active.

Sets the maximum number of simultaneously open user-declared cursors allowed per transaction. Note that an open cursor will hold an active query slot in a resource queue. Used for resource management.

Value Range	Default	Set Classifications
integer	64	coordinator, system, restart

max_resource_queues

> **Note** The `max_resource_queues` server configuration parameter is enforced only when resource queue-based resource management is active.

Sets the maximum number of resource queues that can be created in a WarehousePG cluster. Note that resource queues are system-wide (as are roles) so they apply to all databases in the system.

Value Range	Default	Set Classifications
integer	9	coordinator, system, restart

max_slot_wal_keep_size

Sets the maximum size in megabytes of Write-Ahead Logging (WAL) files on disk per segment instance that can be reserved when WarehousePG streams data to the mirror segment instance or standby coordinator to keep it synchronized with the corresponding primary segment instance or coordinator. The default is -1; when set to the default, WarehousePG can retain an unlimited amount of WAL files on disk.

If the file size exceeds the maximum size, the files are released and are available for deletion. A mirror or standby may no longer be able to continue replication due to removal of required WAL files.

In WarehousePG, replication slots exist internally by default for primary/mirror pairs. Consequently, even if you do not configure this parameter, that functionality is available by default.

> **CAUTION** If `max_slot_wal_keep_size` is set to a non-default value for acting primaries, full and incremental recovery of their mirrors may not be possible. Depending on the workload on the primary running concurrently with a full recovery, the recovery may fail with a missing WAL error. Therefore, you must ensure that `max_slot_wal_keep_size` is set to the default of `-1` or a high enough value before running full recovery. Similarly, depending on how behind the downed mirror is, an incremental recovery of it may fail with a missing WAL error. In this case, full recovery would be the only recourse.

Value Range	Default	Set Classifications
Integer	-1	local, system, reload

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max_stack_depth

Specifies the maximum safe depth of the server's execution stack. The ideal setting for this parameter is the actual stack size limit enforced by the kernel (as set by *ulimit -s* or local equivalent), less a safety margin of a megabyte or so. Setting the parameter higher than the actual kernel limit will mean that a runaway recursive function can crash an individual backend process.

Value Range	Default	Set Classifications
number of kilobytes	2MB	local, session, reload

max_statement_mem

Sets the maximum memory limit for a query. Helps avoid out-of-memory errors on a segment host during query processing as a result of setting statement_mem too high.

Taking into account the configuration of a single segment host, calculate `max_statement_mem` as follows:

```
(seghost_physical_memory) / (average_number_concurrent_queries)
```

When changing both `max_statement_mem` and `statement_mem`, `max_statement_mem` must be changed first, or listed first in the postgresql.conf file.

Value Range	Default	Set Classifications
number of kilobytes	2000MB	coordinator, session, reload, superuser

max_wal_size

Sets the WAL size at which to trigger a checkpoint. This is the maximum size WarehousePG allows the WAL to grow during automatic checkpoints. This is a soft limit; WAL size can exceed `max_wal_size` under special circumstances, such as heavy load, a failing archive_command, or a high `wal_keep_segments` setting.

If you specify this value without units, it is taken as megabytes. The default is 1 GB.

Increasing this parameter can increase the amount of time needed for crash recovery.

You can set this parameter only in the `postgresql.conf` file or on the server command line.

Value Range	Default	Set Classifications
2 - `MAX_KILOBYTES` (integer)	1024	local, system, reload

min_wal_size

Sets the minimum size to which to shrink the WAL. As long as WAL disk usage stays below this setting, WarehousePG always recycles old WAL files for future use at a checkpoint, rather than remove them. You can use this parameter to ensure that enough WAL space is reserved to handle spikes in WAL usage, for example when running large batch jobs.

If you specify this value without units, it is taken as megabytes. The default is `320` MB.

You can set this parameter only in the `postgresql.conf` file or on the server command line.

Value Range	Default	Set Classifications
2 - `MAX_KILOBYTES` (integer)	320	local, system, reload

optimizer

Activates or deactivates GPORCA when running SQL queries. The default is `on`. If you deactivate GPORCA, WarehousePG uses only the Postgres-based planner.

GPORCA co-exists with the Postgres-based planner. With GPORCA enabled, WarehousePG uses GPORCA to generate an execution plan for a query when possible. If GPORCA cannot be used, then the Postgres-based planner is used.

The optimizer parameter can be set for a database system, an individual database, or a session or query.

For information about the Postgres-based planner and GPORCA, see SQL: Querying Data in the *WarehousePG Administrator Guide*.

Value Range	Default	Set Classifications
Boolean	on	coordinator, session, reload

optimizer_analyze_root_partition

For a partitioned table, controls whether the `ROOTPARTITION` keyword is required to collect root partition statistics when the `ANALYZE` command is run on the table. GPORCA uses the root partition statistics when generating a query plan. The Postgres-based planner does not use these statistics.

The default setting for the parameter is `on`, the `ANALYZE` command can collect root partition statistics without the `ROOTPARTITION` keyword. Root partition statistics are collected when you run `ANALYZE` on the root partition, or when you run `ANALYZE` on a leaf partition of the partitioned table and the other leaf partitions have statistics. When the value is `off`, you must run `ANALZYE ROOTPARTITION` to collect root partition statistics.

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When the value of the server configuration parameter optimizer is `on` (the default), the value of this parameter should also be `on`. For information about collecting table statistics on partitioned tables, see ANALYZE.

For information about the Postgres-based planner and GPORCA, see SQL: Querying Data in the *WarehousePG Administrator Guide*.

Value Range	Default	Set Classifications
Boolean	on	coordinator, session, reload

optimizer_array_expansion_threshold

When GPORCA is enabled (the default) and is processing a query that contains a predicate with a constant array, the `optimizer_array_expansion_threshold` parameter limits the optimization process based on the number of constants in the array. If the array in the query predicate contains more than the number elements specified by parameter, GPORCA deactivates the transformation of the predicate into its disjunctive normal form during query optimization.

The default value is 20.

For example, when GPORCA is running a query that contains an `IN` clause with more than 20 elements, GPORCA does not transform the predicate into its disjunctive normal form during query optimization to reduce optimization time consume less memory. The difference in query processing can be seen in the filter condition for the `IN` clause of the query `EXPLAIN` plan.

Changing the value of this parameter changes the trade-off between a shorter optimization time and lower memory consumption, and the potential benefits from constraint derivation during query optimization, for example conflict detection and partition elimination.

The parameter can be set for a database system, an individual database, or a session or query.

Value Range	Default	Set Classifications
Integer > 0	20	coordinator, session, reload

optimizer_control

Controls whether the server configuration parameter optimizer can be changed with SET, the RESET command, or the WarehousePG utility gpconfig. If the `optimizer_control` parameter value is `on`, users can set the optimizer parameter. If the `optimizer_control` parameter value is `off`, the optimizer parameter cannot be changed.

Value Range	Default	Set Classifications
Boolean	on	coordinator, session, reload, superuser

optimizer_cost_model

When GPORCA is enabled (the default), this parameter controls the cost model that GPORCA chooses for bitmap scans used with bitmap indexes or with btree indexes on AO tables.

- `legacy` - preserves the calibrated cost model used by GPORCA in WarehousePG releases 6.13 and earlier
- `calibrated` - improves cost estimates for indexes
- `experimental` - reserved for future experimental cost models; currently equivalent to the `calibrated` model

The default cost model, `calibrated`, is more likely to choose a faster bitmap index with nested loop joins instead of hash joins.

Value Range	Default	Set Classifications
legacy, calibrated, experimental	calibrated	coordinator, session, reload

optimizer_cte_inlining_bound

When GPORCA is enabled (the default), this parameter controls the amount of inlining performed for common table expression (CTE) queries (queries that contain a `WITH` clause). The default value, 0, deactivates inlining.

The parameter can be set for a database system, an individual database, or a session or query.

Value Range	Default	Set Classifications
Decimal >= 0	0	coordinator, session, reload

optimizer_dpe_stats

When GPORCA is enabled (the default) and this parameter is `true` (the default), GPORCA derives statistics that allow it to more accurately estimate the number of rows to be scanned during dynamic partition elimination.

The parameter can be set for a database system, an individual database, or a session or query.

Value Range	Default	Set Classifications
Boolean	true	coordinator, session, reload

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optimizer_discard_redistribute_hashjoin

When GPORCA is enabled (the default), this parameter specifies whether the query optimizer should eliminate plans that include a HashJoin operator with a Redistribute Motion child. Eliminating such plans can improve performance in cases where the data being joined exhibits high skewness in the join keys.

The default setting is `off`, GPORCA considers all plan alternatives, including those with a Redistribute Motion child, in the HashJoin operator. If you observe performance issues with queries that use a HashJoin with highly skewed data, you may want to consider setting `optimizer_discard_redistribute_hashjoin` to `on` to instruct GPORCA to discard such plans.

Value Range	Default	Set Classifications
Boolean	off	coordinator, session, reload

optimizer_enable_associativity

When GPORCA is enabled (the default), this parameter controls whether the join associativity transform is enabled during query optimization. The transform analyzes join orders. For the default value `off`, only the GPORCA dynamic programming algorithm for analyzing join orders is enabled. The join associativity transform largely duplicates the functionality of the newer dynamic programming algorithm.

If the value is `on`, GPORCA can use the associativity transform during query optimization.

The parameter can be set for a database system, an individual database, or a session or query.

For information about GPORCA, see About GPORCA in the *WarehousePG Administrator Guide*.

Value Range	Default	Set Classifications
Boolean	off	coordinator, session, reload

optimizer_enable_dml

When GPORCA is enabled (the default) and this parameter is `true` (the default), GPORCA attempts to run DML commands such as `INSERT`, `UPDATE`, and `DELETE`. If GPORCA cannot run the command, WarehousePG falls back to the Postgres-based planner.

When set to `false`, WarehousePG always falls back to the Postgres-based planner when performing DML commands.

The parameter can be set for a database system, an individual database, or a session or query.

For information about GPORCA, see About GPORCA in the *WarehousePG Administrator Guide*.

Value Range	Default	Set Classifications
Boolean	true	coordinator, session, reload

optimizer_enable_dynamicindexonlyscan

When GPORCA is enabled (the default), the `optimizer_enable_dynamicindexonlyscan` parameter controls generation of dynamic index-only scan plan types.

The default value is `on`, GPORCA may generate a dynamic index only scan alternative when planning a query on a partitioned table that does not include single row volatile (SIRV) functions.

When set to `off`, GPORCA does not generate dynamic index-only scan plan alternatives.

The parameter can be set for a database system, an individual database, or a session or query.

Value Range	Default	Set Classifications
Boolean	on	coordinator, session, reload

optimizer_enable_foreign_table

When GPORCA is enabled (the default) and this configuration parameter is `true` (the default), GPORCA generates plans for queries that involve foreign tables. When `false`, queries that include foreign tables fall back to the Postgres-based planner.

Value Range	Default	Set Classifications
Boolean	true	coordinator, session, reload

optimizer_enable_indexonlyscan

When GPORCA is enabled (the default) and this parameter is `true` (the default), GPORCA can generate index-only scan plan types for B-tree indexes and any index type that contains all of the columns used by the query inside the index. (GiST indexes support index-only scans for some operator classes but not others.) GPORCA accesses the index values only, not the data blocks of the relation. This provides a query execution performance improvement, particularly when the table has been vacuumed, has wide columns, and GPORCA does not need to fetch any data blocks (for example, they are visible).

When deactivated (`false`), GPORCA does not generate index-only scan plan types.

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The parameter can be set for a database system, an individual database, or a session or query.

For information about GPORCA, see About GPORCA in the *WarehousePG Administrator Guide*.

Value Range	Default	Set Classifications
Boolean	true	coordinator, session, reload

optimizer_enable_coordinator_only_queries

When GPORCA is enabled (the default), this parameter allows GPORCA to run catalog queries that run only on the WarehousePG coordinator. For the default value `off`, only the Postgres-based planner can run catalog queries that run only on the WarehousePG coordinator.

The parameter can be set for a database system, an individual database, or a session or query.

> **Note** Enabling this parameter decreases performance of short running catalog queries. To avoid this issue, set this parameter only for a session or a query.

For information about GPORCA, see About GPORCA in the *WarehousePG Administrator Guide*.

Value Range	Default	Set Classifications
Boolean	off	coordinator, session, reload

optimizer_enable_multiple_distinct_aggs

When GPORCA is enabled (the default), this parameter allows GPORCA to support Multiple Distinct Qualified Aggregates, such as `SELECT count(DISTINCT a),sum(DISTINCT b) FROM foo`. This parameter is deactivated by default because its plan is generally suboptimal in comparison to the plan generated by the Postgres-based planner.

The parameter can be set for a database system, an individual database, or a session or query.

For information about GPORCA, see About GPORCA in the *WarehousePG Administrator Guide*.

Value Range	Default	Set Classifications
Boolean	off	coordinator, session, reload

optimizer_enable_orderedagg

When GPORCA is enabled (the default), this parameter determines whether or not GPORCA generates a query plan for ordered aggregates.

The default value is `on`, GPORCA generates a plan for a query that includes an ordered aggregate. When `off`, the query falls back to the Postgres-based planner.

You can set this parameter for a database system, an individual database, or a session or query.

Value Range	Default	Set Classifications
Boolean	on	coordinator, session, reload

optimizer_enable_push_join_below_union_all

When GPORCA is enabled (the default), the `optimizer_enable_push_join_below_union_all` parameter controls GPORCA's behaviour when it encounters a query that includes a `JOIN` of a `UNION ALL`.

The default value is `off`, GPORCA performs no transforms when a query includes a `JOIN` of a `UNION ALL`.

When set to `on` and the plan cost makes it eligible, GPORCA transforms a `JOIN` of `UNION ALL` to a `UNION ALL` of `JOIN`s. This transform may improve join performance when the `UNION ALL` children can benefit from join operations for which they are not eligible. Such an example is an indexed nested loop join, which is highly performant when the inner side is large and indexed, and the outer side is small. When the `UNION ALL` of multiple indexed large tables is joined with a small table, this transform pushes the join condition down as the index condition, and generates a more performant query than that utilizing a hash join.

Enabling this transform may increase planning time, so be sure to run and examine `EXPLAIN` output for the query with both parameter settings.

The `optimizer_enable_push_join_below_union_all` parameter can be set for a database system, an individual database, or a session or query.

Value Range	Default	Set Classifications
Boolean	off	coordinator, session, reload

optimizer_enable_replicated_table

When GPORCA is enabled (the default), this parameter controls GPORCA's behavior when it encounters DML operations on a replicated table.

The default value is `on`, GPORCA attempts to plan and execute operations on replicated tables. When `off`, GPORCA immediately falls back to the Postgres-based planner when it detects replicated table operations.

The parameter can be set for a database system, an individual database, or a session or query.

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For information about GPORCA, see About GPORCA in the *WarehousePG Administrator Guide*.

Value Range	Default	Set Classifications
Boolean	on	coordinator, session, reload

optimizer_enable_right_outer_join

When GPORCA is enabled (the default), this parameter allows you to control whether GPORCA generates right outer joins.

When set to the default value of `on`, GPORCA may both generate right outer joins and convert left outer joins to right outer joins if the situation calls for it. By setting this to `off`, you force GPORCA to generate equivalent left outer joins for incoming right outer joins and never generate right outer joins.

In situations in which you are observing poor performance related to right outer joins you may choose to suppress their use by setting this parameter to `off`.

You may set this parameter for a database system, an individual database, or a session or query. However, we recommend that you set this parameter at the query level, as there are a number of use cases where right outer join is the correct query plan alternative to choose.

For information about GPORCA, see the About GPORCA topic.

Value Range	Default	Set Classifications
Boolean	on	coordinator, session, reload

optimizer_force_agg_skew_avoidance

When GPORCA is enabled (the default), this parameter affects the query plan alternatives that GPORCA considers when 3 stage aggregate plans are generated. When the value is `true`, the default, GPORCA considers only 3 stage aggregate plans where the intermediate aggregation uses the `GROUP BY` and `DISTINCT` columns for distribution to reduce the effects of processing skew.

If the value is `false`, GPORCA can also consider a plan that uses `GROUP BY` columns for distribution. These plans might perform poorly when processing skew is present.

For information about GPORCA, see About GPORCA in the *WarehousePG Administrator Guide*.

Value Range	Default	Set Classifications
Boolean	true	coordinator, session, reload

optimizer_force_comprehensive_join_implementation

When GPORCA is enabled (the default), this parameter affects its consideration of nested loop join and hash join alternatives.

The default value is `false`, GPORCA does not consider nested loop join alternatives when a hash join is available, which significantly improves optimization performance for most queries. When set to `true`, GPORCA will explore nested loop join alternatives even when a hash join is possible.

Value Range	Default	Set Classifications
Boolean	false	coordinator, session, reload

optimizer_force_multistage_agg

For the default settings, GPORCA is enabled and this parameter is `false`, GPORCA makes a cost-based choice between a one- or two-stage aggregate plan for a scalar distinct qualified aggregate. When `true`, GPORCA chooses a multi-stage aggregate plan when such a plan alternative is generated.

The parameter can be set for a database system, an individual database, or a session or query.

Value Range	Default	Set Classifications
Boolean	false	coordinator, session, reload

optimizer_force_three_stage_scalar_dqa

For the default settings, GPORCA is enabled and this parameter is `true`, GPORCA chooses a plan with multistage aggregates when such a plan alternative is generated. When the value is `false`, GPORCA makes a cost based choice rather than a heuristic choice.

The parameter can be set for a database system, an individual database, or a session, or query.

Value Range	Default	Set Classifications
Boolean	true	coordinator, session, reload

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optimizer_jit_above_cost

When using GPORCA, sets the query cost above which JIT compilation is activated when JIT is enabled. Performing JIT compilation costs planning time but can accelerate query execution. Note that setting the JIT cost parameters to '0' forces all queries to be JIT-compiled and, as a result, slows down queries. Setting it to a negative value disables JIT compilation.

Value Range	Default	Set Classifications
Floating point	7500	coordinator, session, reload

optimizer_jit_inline_above_cost

When using GPORCA, sets the query cost above which JIT compilation attempts to inline functions and operators. Inlining adds planning time, but can improve execution speed. It is not meaningful to set this to less than jit_above_cost. Note that setting the JIT cost parameters to '0' forces all queries to be JIT-compiled and, as a result, slows down queries. Setting it to a negative value disables inlining.

Value Range	Default	Set Classifications
Floating point	37500	coordinator, session, reload

optimizer_jit_optimize_above_cost

When using GPORCA, sets the query cost above which JIT compilation applies expensive optimizations. Such optimization adds planning time, but can improve execution speed. It is not meaningful to set this to less than `optimizer_jit_above_cost`, and it is unlikely to be beneficial to set it to more than `optimizer_jit_inline_above_cost`. Note that setting the JIT cost parameters to '0' forces all queries to be JIT-compiled and, as a result, slows down queries. Setting it to a negative value disables expensive optimizations.

Value Range	Default	Set Classifications
Floating point	37500	coordinator, session, reload

optimizer_join_arity_for_associativity_commutativity

The value is an optimization hint to limit the number of join associativity and join commutativity transformations explored during query optimization. The limit controls the alternative plans that GPORCA considers during query optimization. For example, the default value of 18 is an optimization hint for GPORCA to stop exploring join associativity and join commutativity transformations when an n-ary join operator has more than 18 children during optimization.

For a query with a large number of joins, specifying a lower value improves query performance by limiting the number of alternate query plans that GPORCA evaluates. However, setting the value too low might cause GPORCA to generate a query plan that performs sub-optimally.

This parameter has no effect when the `optimizer_join_order` parameter is set to `query` or `greedy`.

This parameter can be set for a database system or a session.

Value Range	Default	Set Classifications
integer > 0	18	local, system, reload

optimizer_join_order

When GPORCA is enabled (the default), this parameter sets the join enumeration algorithm:

- `query` - Uses the join order specified in the query.
- `greedy` - Evaluates the join order specified in the query and alternatives based on minimum cardinalities of the relations in the joins.
- `exhaustive` - Applies transformation rules to find and evaluate up to a configurable threshold number (`optimizer_join_order_threshold`, default 10) of n-way inner joins, and then uses the `greedy` method for the remainder. While planning time drops significantly at that point, plan quality and execution time may get worse.
- `exhaustive2` - Operates with an emphasis on generating join orders that are suitable for dynamic partition elimination. This algorithm applies transformation rules to find and evaluate n-way inner and outer joins. When evaluating very large joins with more than `optimizer_join_order_threshold` (default 10) tables, this algorithm employs a gradual transition to the `greedy` method; planning time goes up smoothly as the query gets more complicated, and plan quality and execution time only gradually degrade. `exhaustive2` provides a good trade-off between planning time and execution time for many queries.

The default value is `exhaustive2`.

Setting this parameter to `query` or `greedy` can generate a suboptimal query plan. However, if the administrator is confident that a satisfactory plan is generated with the `query` or `greedy` setting, query optimization time can be improved by setting the parameter to the lower optimization level.

Setting this parameter to `query` or `greedy` overrides the `optimizer_join_order_threshold` and `optimizer_join_arity_for_associativity_commutativity` parameters.

This parameter can be set for an individual database, a session, or a query.

Value Range	Default	Set Classifications
query, greedy, exhaustive, exhaustive2	exhaustive2	coordinator, session, reload

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optimizer_join_order_threshold

When GPORCA is enabled (the default), this parameter sets the maximum number of join children for which GPORCA will use the dynamic programming-based join ordering algorithm. You can set this value for a single query or for an entire session.

This parameter has no effect when the `optimizer_join_query` parameter is set to `query` or `greedy`.

Value Range	Default	Set Classifications
0 - 12	10	coordinator, session, reload

optimizer_mdcache_size

Sets the maximum amount of memory on the WarehousePG coordinator that GPORCA uses to cache query metadata (optimization data) during query optimization. The memory limit session based. GPORCA caches query metadata during query optimization with the default settings: GPORCA is enabled and optimizer_metadata_caching is `on`.

The default value is 16384 (16MB). This is an optimal value that has been determined through performance analysis.

You can specify a value in KB, MB, or GB. The default unit is KB. For example, a value of 16384 is 16384KB. A value of 1GB is the same as 1024MB or 1048576KB. If the value is 0, the size of the cache is not limited.

This parameter can be set for a database system, an individual database, or a session or query.

Value Range	Default	Set Classifications
Integer >= 0	16384	coordinator, session, reload

optimizer_metadata_caching

When GPORCA is enabled (the default), this parameter specifies whether GPORCA caches query metadata (optimization data) in memory on the WarehousePG coordinator during query optimization. The default for this parameter is `on`, enable caching. The cache is session based. When a session ends, the cache is released. If the amount of query metadata exceeds the cache size, then old, unused metadata is evicted from the cache.

If the value is `off`, GPORCA does not cache metadata during query optimization.

This parameter can be set for a database system, an individual database, or a session or query.

The server configuration parameter optimizer_mdcache_size controls the size of the query metadata cache.

Value Range	Default	Set Classifications
Boolean	on	coordinator, session, reload

optimizer_minidump

GPORCA generates minidump files to describe the optimization context for a given query. The information in the file is not in a format that can be easily used for debugging or troubleshooting. The minidump file is located under the coordinator data directory and uses the following naming format:

```
Minidump_date_time.mdp
```

The minidump file contains this query related information:

- Catalog objects including data types, tables, operators, and statistics required by GPORCA
- An internal representation (DXL) of the query
- An internal representation (DXL) of the plan produced by GPORCA
- System configuration information passed to GPORCA such as server configuration parameters, cost and statistics configuration, and number of segments
- A stack trace of errors generated while optimizing the query

Setting this parameter to `ALWAYS` generates a minidump for all queries. Set this parameter to `ONERROR` to minimize total optimization time.

For information about GPORCA, see About GPORCA in the *WarehousePG Administrator Guide*.

Value Range	Default	Set Classifications
ONERROR, ALWAYS	ONERROR	coordinator, session, reload

optimizer_nestloop_factor

This parameter adds a costing factor to GPORCA to prioritize hash joins instead of nested loop joins during query optimization. The default value of 1024 was chosen after evaluating numerous workloads with uniformly distributed data. 1024 should be treated as the practical upper bound setting for this parameter. If you find the GPORCA selects hash joins more often than it should, reduce the value to shift the costing factor in favor of nested loop joins.

The parameter can be set for a database system, an individual database, or a session or query.

Value Range	Default	Set Classifications
INT_MAX > 1	1024	coordinator, session, reload

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optimizer_parallel_union

When GPORCA is enabled (the default), `optimizer_parallel_union` controls the amount of parallelization that occurs for queries that contain a `UNION` or `UNION ALL` clause.

When the value is `off`, the default, GPORCA generates a query plan where each child of an APPEND(UNION) operator is in the same slice as the APPEND operator. During query execution, the children are run in a sequential manner.

When the value is `on`, GPORCA generates a query plan where a redistribution motion node is under an APPEND(UNION) operator. During query execution, the children and the parent APPEND operator are on different slices, allowing the children of the APPEND(UNION) operator to run in parallel on segment instances.

The parameter can be set for a database system, an individual database, or a session or query.

Value Range	Default	Set Classifications
boolean	off	coordinator, session, reload

optimizer_penalize_skew_broadcast_threshold

When GPORCA is enabled (the default), during query optimization GPORCA penalizes the cost of plans that attempt to broadcast more than the value specified by `optimizer_penalize_broadcast_threshold`. For example, if this parameter is set to 100K rows (the default), any broadcast of more than 100K rows is heavily penalized.

When this parameter is set to `0`, GPORCA sets this broadcast threshold to unlimited and never penalizes a broadcast motion.

Value Range	Default	Set Classifications
integer >= 0	100K rows	coordinator, session, reload

optimizer_penalize_skew

When GPORCA is enabled (the default), this parameter allows GPORCA to penalize the local cost of a HashJoin with a skewed Redistribute Motion as child to favor a Broadcast Motion during query optimization. The default value is `true`.

GPORCA determines there is skew for a Redistribute Motion when the NDV (number of distinct values) is less than the number of segments.

The parameter can be set for a database system, an individual database, or a session or query.

For information about GPORCA, see About GPORCA in the *WarehousePG Administrator Guide*.

Value Range	Default	Set Classifications
Boolean	true	coordinator, session, reload

optimizer_print_missing_stats

When GPORCA is enabled (the default), this parameter controls the display of table column information about columns with missing statistics for a query. The default value is `true`, display the column information to the client. When the value is `false`, the information is not sent to the client.

The information is displayed during query execution, or with the `EXPLAIN` or `EXPLAIN ANALYZE` commands.

The parameter can be set for a database system, an individual database, or a session.

Value Range	Default	Set Classifications
Boolean	true	coordinator, session, reload

optimizer_print_optimization_stats

When GPORCA is enabled (the default), this parameter enables logging of GPORCA query optimization statistics for various optimization stages for a query. The default value is off, do not log optimization statistics. To log the optimization statistics, this parameter must be set to on and the parameter client_min_messages must be set to log.

- `set optimizer_print_optimization_stats = on;`
- `set client_min_messages = 'log';`

The information is logged during query execution, or with the `EXPLAIN` or `EXPLAIN ANALYZE` commands.

This parameter can be set for a database system, an individual database, or a session or query.

Value Range	Default	Set Classifications
Boolean	off	coordinator, session, reload

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optimizer_skew_factor

When GPORCA is enabled (the default), `optimizer_skew_factor` controls skew ratio computation.

The default value is `0`, skew computation is turned off for GPORCA. To enable skew computation, set `optimizer_skew_factor` to a value between `1` and `100`, inclusive.

The larger the `optimizer_skew_factor`, the larger the cost that GPORCA assigns to redistributed hash join, such that GPORCA favors more a broadcast hash join.

The parameter can be set for a database system, an individual database, or a session or query.

Value Range	Default	Set Classifications
integer 0-100	0	coordinator, session, reload

optimizer_sort_factor

When GPORCA is enabled (the default), `optimizer_sort_factor` controls the cost factor to apply to sorting operations during query optimization. The default value `1` specifies the default sort cost factor. The value is a ratio of increase or decrease from the default factor. For example, a value of `2.0` sets the cost factor at twice the default, and a value of `0.5` sets the factor at half the default.

The parameter can be set for a database system, an individual database, or a session or query.

Value Range	Default	Set Classifications
Decimal > 0	1	coordinator, session, reload

optimizer_use_gpdb_allocators

When GPORCA is enabled (the default) and this parameter is `true` (the default), GPORCA uses WarehousePG memory management when running queries. When set to `false`, GPORCA uses GPORCA-specific memory management. WarehousePG memory management allows for faster optimization, reduced memory usage during optimization, and improves GPORCA support of vmem limits when compared to GPORCA-specific memory management.

For information about GPORCA, see About GPORCA in the *WarehousePG Administrator Guide*.

Value Range	Default	Set Classifications
Boolean	true	coordinator, system, restart

optimizer_xform_bind_threshold

When GPORCA is enabled (the default), this parameter controls the maximum number of bindings per transform that GPORCA produces per group expression. Setting this parameter limits the number of alternatives that GPORCA creates, in many cases reducing the optimization time and overall memory usage of queries that include deeply nested expressions.

The default value is `0`, GPORCA produces an unlimited set of bindings.

Value Range	Default	Set Classifications
0 - INT_MAX	0	coordinator, session, reload

password_encryption

When a password is specified in CREATE ROLE or ALTER ROLE, this parameter determines the algorithm to use to encrypt the password. Possible values are scram-sha-256, which will encrypt the password with SCRAM-SHA-256, and md5, which stores the password as an MD5 hash. The default is md5.

Value Range	Default	Set Classifications
md5, scram-sha-256	md5	coordinator, session, reload

plan_cache_mode

Prepared statements (either explicitly prepared or implicitly generated, for example by PL/pgSQL) can be run using *custom* or *generic* plans. Custom plans are created for each execution using its specific set of parameter values, while generic plans do not rely on the parameter values and can be re-used across executions. The use of a generic plan saves planning time, but if the ideal plan depends strongly on the parameter values, then a generic plan might be inefficient. The choice between these options is normally made automatically, but it can be overridden by setting the `plan_cache_mode` parameter. If the prepared statement has no parameters, a generic plan is always used.

The allowed values are `auto` (the default), `force_custom_plan` and `force_generic_plan`. This setting is considered when a cached plan is to be run, not when it is prepared. For more information seePREPARE.

The parameter can be set for a database system, an individual database, a session, or a query.

Value Range	Default	Set Classifications
auto, force_custom_plan, force_generic_plan	auto	coordinator, session, reload

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pljava_classpath

A colon (`:`) separated list of jar files or directories containing jar files needed for PL/Java functions. The full path to the jar file or directory must be specified, except the path can be omitted for jar files in the `$GPHOME/lib/postgresql/java` directory. The jar files must be installed in the same locations on all WarehousePG hosts and readable by the `gpadmin` user.

The `pljava_classpath` parameter is used to assemble the PL/Java classpath at the beginning of each user session. Jar files added after a session has started are not available to that session.

If the full path to a jar file is specified in `pljava_classpath` it is added to the PL/Java classpath. When a directory is specified, any jar files the directory contains are added to the PL/Java classpath. The search does not descend into subdirectories of the specified directories. If the name of a jar file is included in `pljava_classpath` with no path, the jar file must be in the `$GPHOME/lib/postgresql/java` directory.

> **Note** Performance can be affected if there are many directories to search or a large number of jar files.

If pljava_classpath_insecure is `false` , setting the `pljava_classpath` parameter requires superuser privilege. Setting the classpath in SQL code will fail when the code is run by a user without superuser privilege. The `pljava_classpath` parameter must have been set previously by a superuser or in the `postgresql.conf` file. Changing the classpath in the `postgresql.conf` file requires a reload (`gpstop -u`).

Value Range	Default	Set Classifications
string		coordinator, session, reload, superuser

pljava_classpath_insecure

Controls whether the server configuration parameter pljava_classpath can be set by a user without WarehousePG superuser privileges. When `true` , `pljava_classpath` can be set by a regular user. Otherwise, pljava_classpath can be set only by a database superuser. The default is `false` .

> **Caution** Enabling this parameter exposes a security risk by giving non-administrator database users the ability to run unauthorized Java methods.

Value Range	Default	Set Classifications
Boolean	false	coordinator, session, reload, superuser

pljava_statement_cache_size

Sets the size in KB of the JRE MRU (Most Recently Used) cache for prepared statements.

Value Range	Default	Set Classifications
number of kilobytes	10	coordinator, system, reload, superuser

pljava_release_lingering_savepoints

If true, lingering savepoints used in PL/Java functions will be released on function exit. If false, savepoints will be rolled back.

Value Range	Default	Set Classifications
Boolean	true	coordinator, system, reload, superuser

pljava_vmoptions

Defines the startup options for the Java VM. The default value is an empty string ("").

Value Range	Default	Set Classifications
string		coordinator, system, reload, superuser

port

The database listener port for a WarehousePG instance. The coordinator and each segment has its own port. Port numbers for the WarehousePG cluster must also be changed in the `gp_segment_configuration` catalog. You must shut down your WarehousePG cluster before changing port numbers.

Value Range	Default	Set Classifications
any valid port number	5432	local, system, restart

quote_all_identifiers

Ensures that all identifiers are quoted, even if they are not keywords, when the database generates SQL. See also the `--quote-all-identifiers` option of pg_dump and pg_dumpall.

Value Range	Default	Set Classifications
Boolean	false	local, session, reload

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random_page_cost

Sets the estimate of the cost of a nonsequentially fetched disk page for the Postgres-based planner. This is measured as a multiple of the cost of a sequential page fetch. A higher value makes it more likely a sequential scan will be used, a lower value makes it more likely an index scan will be used.

Value Range	Default	Set Classifications
floating point	100	coordinator, session, reload

readable_external_table_timeout

When an SQL query reads from an external table, the parameter value specifies the amount of time in seconds that WarehousePG waits before cancelling the query when data stops being returned from the external table.

The default value of 0, specifies no time out. WarehousePG does not cancel the query.

If queries that use gpfdist run a long time and then return the error "intermittent network connectivity issues", you can specify a value for `readable_external_table_timeout`. If no data is returned by gpfdist for the specified length of time, WarehousePG cancels the query.

Value Range	Default	Set Classifications
integer >= 0	0	coordinator, system, reload

repl_catchup_within_range

For WarehousePG coordinator mirroring, controls updates to the active coordinator. If the number of WAL segment files that have not been processed by the `walsender` exceeds this value, WarehousePG updates the active coordinator.

If the number of segment files does not exceed the value, WarehousePG blocks updates to the to allow the `walsender` process the files. If all WAL segments have been processed, the active coordinator is updated.

Value Range	Default	Set Classifications
0 - 64	1	coordinator, system, reload, superuser

wal_buffers

Sets the number of disk-page buffers in shared memory for WAL. This is the amount of shared memory used for WAL data that has not yet been written to disk. The default setting of `-1` selects a size equal to 1/32nd (about 3%) of shared_buffers, but not less than `64kB` nor more than the size of one WAL segment, typically `16MB`. You can set this value manually if the automatic choice is too large or too small, but WarehousePG treats any positive value less than `32kB` as `32kB`. If you specify this value without units, it is taken as WAL blocks, that is `XLOG_BLCKSZ` bytes, typically 32kB.

You can set this parameter only at server start.

The contents of the WAL buffers are written out to disk at every transaction commit, so extremely large values are unlikely to provide a significant benefit. However, setting this value to at least a few megabytes can improve write performance on a busy server where many clients are committing at once. The auto-tuning selected by the default setting of `-1` should give reasonable results in most cases.

Value Range	Default	Set Classifications
-1 - (INT_MAX / XLOG_BLCKSZ) (integer)	-1	local, system, restart

wal_compression

Enables compression of full page writes in a WAL file. This parameter can only be changed by superusers.

> **Note** `wal_compression` can reduce the WAL volume without increasing the risk of unrecoverable data corruption, but at the cost of some extra CPU spent on the compression during WAL logging and on the decompression during WAL replay.

Value Range	Default	Set Classifications
Boolean	on	local, session, reload, superuser

wal_sender_timeout

For WarehousePG coordinator mirroring, sets the maximum time in milliseconds that the `walsender` process on the active coordinator waits for a status message from the `walreceiver` process on the standby coordinator. If a message is not received, the `walsender` logs an error message.

The wal_receiver_status_interval controls the interval between `walreceiver` status messages.

Value Range	Default	Set Classifications
0 - INT_MAX	60000 ms (60 seconds)	coordinator, system, reload, superuser

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resource_cleanup_gangs_on_wait

> **Note** The `resource_cleanup_gangs_on_wait` server configuration parameter is enforced only when resource queue-based resource management is active.

If a statement is submitted through a resource queue, clean up any idle query executor worker processes before taking a lock on the resource queue.

Value Range	Default	Set Classifications
Boolean	on	coordinator, session, reload

resource_select_only

> **Note** The `resource_select_only` server configuration parameter is enforced only when resource queue-based resource management is active.

Sets the types of queries managed by resource queues. If set to on, then `SELECT`, `SELECT INTO`, `CREATE TABLE AS SELECT`, and `DECLARE CURSOR` commands are evaluated. If set to off `INSERT`, `UPDATE`, and `DELETE` commands will be evaluated as well.

Value Range	Default	Set Classifications
Boolean	off	coordinator, system, restart

row_security

> **Note** This configuration parameter has no effect on roles which bypass every row security policy, for example, superusers and roles configured with the `BYPASSRLS` attribute.

Controls whether to raise an error in lieu of applying a row security policy. When set to `on`, policies apply normally. When set to `off`, queries which would otherwise apply at least one policy fail.

The default is `on`. Change `row_security` to `off` where limited row visibility could cause incorrect results; for example, `pg_dump` makes that change by default.

For more information about row-level security policies, see CREATE POLICY.

Value Range	Default	Set Classifications
Boolean	on	coordinator, system, restart

runaway_detector_activation_percent

For queries that are managed by resource queues or resource groups, this parameter determines when WarehousePG terminates running queries based on the amount of memory the queries are using. A value of 100 deactivates the automatic termination of queries based on the percentage of memory that is utilized.

Either the resource queue or the resource group management scheme can be active in WarehousePG; both schemes cannot be active at the same time. The server configuration parameter gp_resource_manager controls which scheme is active.

This parameter sets the percent of utilized WarehousePG virtual memory that triggers the termination of queries. If the percentage of virtual memory that is utilized for a WarehousePG segment exceeds the specified value, WarehousePG terminates queries managed by resource queues based on memory usage, starting with the query consuming the largest amount of memory. Queries are terminated until the percentage of utilized virtual memory is below the specified percentage.

Specify the maximum virtual memory value for active WarehousePG segment instances with the server configuration parameter gp_vmem_protect_limit.

For example, if `gp_vmem_protect_limit` is set to 10GB, and `runaway_detector_activation_percent` is 90 (90%), WarehousePG starts terminating queries when the utilized virtual memory exceeds 9 GB.

For information about resource groups and resource queues, see [Managing Resources]((../../admin_guide/wlmgmt.html).

Value Range	Default	Set Classifications
percentage (integer)	90	local, system, restart

search_path

Specifies the order in which schemas are searched when an object is referenced by a simple name with no schema component. When there are objects of identical names in different schemas, the one found first in the search path is used. The system catalog schema, *pg_catalog*, is always searched, whether it is mentioned in the path or not. When objects are created without specifying a particular target schema, they will be placed in the first schema listed in the search path. The current effective value of the search path can be examined via the SQL function *current_schema()*. *current_schema()* shows how the requests appearing in *search_path* were resolved.

Value Range	Default	Set Classifications
a comma-separated list of schema names	$user,public	coordinator, session, reload

seq_page_cost

For the Postgres-based planner, sets the estimate of the cost of a disk page fetch that is part of a series of sequential fetches.

Value Range	Default	Set Classifications
floating point	1	coordinator, session, reload

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server_encoding

Reports the database encoding (character set). It is determined when the WarehousePG cluster is initialized. Ordinarily, clients need only be concerned with the value of *client_encoding*.

Value Range	Default	Set Classifications
<system dependent>	UTF8	read only

server_version

Reports the version of PostgreSQL that this release of WarehousePG is based on.

Value Range	Default	Set Classifications
string	9.4.20	read only

server_version_num

Reports the version of PostgreSQL that this release of WarehousePG is based on as an integer.

Value Range	Default	Set Classifications
integer	90420	read only

shared_buffers

Sets the amount of memory a WarehousePG segment instance uses for shared memory buffers. This setting must be at least 128KB and at least 16KB times max_connections.

Each WarehousePG segment instance calculates and attempts to allocate certain amount of shared memory based on the segment configuration. The value of `shared_buffers` is significant portion of this shared memory calculation, but is not all it. When setting `shared_buffers`, the values for the operating system parameters `SHMMAX` or `SHMALL` might also need to be adjusted.

The operating system parameter `SHMMAX` specifies maximum size of a single shared memory allocation. The value of `SHMMAX` must be greater than this value:

```
`shared_buffers` + <other_seg_shmem>
```

The value of `other_seg_shmem` is the portion the WarehousePG shared memory calculation that is not accounted for by the `shared_buffers` value. The `other_seg_shmem` value will vary based on the segment configuration.

With the default WarehousePG parameter values, the value for `other_seg_shmem` is approximately 111MB for WarehousePG segments and approximately 79MB for the WarehousePG coordinator.

The operating system parameter `SHMALL` specifies the maximum amount of shared memory on the host. The value of `SHMALL` must be greater than this value:

```
(<num_instances_per_host> * ( `shared_buffers` + <other_seg_shmem> )) + <other_app_shared_mem>
```

The value of `other_app_shared_mem` is the amount of shared memory that is used by other applications and processes on the host.

When shared memory allocation errors occur, possible ways to resolve shared memory allocation issues are to increase `SHMMAX` or `SHMALL`, or decrease `shared_buffers` or `max_connections`.

See the *WarehousePG Installation Guide* for information about the WarehousePG values for the parameters `SHMMAX` and `SHMALL`.

Value Range	Default	Set Classifications
integer > 16K * *max_connections*	125MB	local, system, restart

shared_preload_libraries

A comma-separated list of shared libraries that are to be preloaded at server start. PostgreSQL procedural language libraries can be preloaded in this way, typically by using the syntax `$libdir/plXXX'` where XXX is pgsql, perl, tcl, or python. By preloading a shared library, the library startup time is avoided when the library is first used. If a specified library is not found, the server will fail to start.

> **Note** When you add a library to `shared_preload_libraries`, be sure to retain any previous setting of the parameter.

Value Range	Default	Set Classifications
		local, system, restart

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ssl

Enables SSL connections.

Value Range	Default	Set Classifications
Boolean	off	coordinator, system, restart

ssl_ciphers

Specifies a list of SSL ciphers that are allowed to be used on secure connections. `ssl_ciphers` *overrides* any ciphers string specified in `/etc/openssl.cnf`. The default value `ALL:!ADH:!LOW:!EXP:!MD5:@STRENGTH` enables all ciphers except for ADH, LOW, EXP, and MD5 ciphers, and prioritizes ciphers by their strength.

> **Note** With TLS 1.2 some ciphers in MEDIUM and HIGH strength still use NULL encryption (no encryption for transport), which the default `ssl_ciphers` string allows. To bypass NULL ciphers with TLS 1.2 use a string such as `TLSv1.2:!eNULL:!aNULL`.

See the openssl manual page for a list of supported ciphers.

Value Range	Default	Set Classifications
string	ALL:!ADH:!LOW:!EXP:!MD5:@STRENGTH	coordinator, system, restart

standard_conforming_strings

Determines whether ordinary string literals ('...') treat backslashes literally, as specified in the SQL standard. The default value is on. Turn this parameter off to treat backslashes in string literals as escape characters instead of literal backslashes. Applications may check this parameter to determine how string literals are processed. The presence of this parameter can also be taken as an indication that the escape string syntax (E'...') is supported.

Value Range	Default	Set Classifications
Boolean	on	coordinator, session, reload

statement_mem

Allocates segment host memory per query. The amount of memory allocated with this parameter cannot exceed max_statement_mem or the memory limit on the resource queue or resource group through which the query was submitted. If additional memory is required for a query, temporary spill files on disk are used.

You can use the following calculation to estimate a reasonable `statement_mem` value for a wide variety of situations:

```
( <gp_vmem_protect_limit>GB * .9 ) / <max_expected_concurrent_queries>
```

If you are using resource groups to control resource allocation in your WarehousePG cluster.

- If the server configuration parameter gp_resgroup_memory_query_fixed_mem is set to 0, and the resource group parameter `MEMORY_QUOTA` is set to -1, `statement_mem` sets the amount of memory allocated for a query.
- If you set the configuration parameters gp_resource_group_bypass or gp_resource_group_bypass_catalog_query to bypass the resource group limits, `statement_mem` sets the amount of memory allocated for the query.
- `statement_mem` also sets the amount of memory allocated for a query if its value is greater than `MEMORY_QUOTA` / `CONCURRENCY`.
- Queries whose plan cost is less than the limit `MIN_COST` use `statement_mem` as their memory quota.

If you are using resource queues to control resource allocation in your WarehousePG cluster.

- When gp_resqueue_memory_policy is set to "auto", `statement_mem` and resource queue memory limits control query memory usage.

For information about resource groups and resource queues, see [Managing Resources]((../../admin_guide/wlmgmt.html).

When changing both `max_statement_mem` and `statement_mem`, `max_statement_mem` must be changed first, or listed first in the postgresql.conf file.

Value Range	Default	Set Classifications
number of kilobytes	128MB	coordinator, session, reload

statement_timeout

Abort any statement that takes over the specified number of milliseconds. 0 turns off the limitation.

Value Range	Default	Set Classifications
number of milliseconds	0	coordinator, session, reload

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stats_queue_level

> **Note** The `stats_queue_level` server configuration parameter is enforced only when resource queue-based resource management is active.

Collects resource queue statistics on database activity.

Value Range	Default	Set Classifications
Boolean	off	coordinator, session, reload

superuser_reserved_connections

Determines the number of connection slots that are reserved for WarehousePG superusers.

Value Range	Default	Set Classifications
integer < *max_connections*	10	local, system, restart

tcp_keepalives_count

How many keepalives may be lost before the connection is considered dead. A value of 0 uses the system default. If TCP_KEEPCNT is not supported, this parameter must be 0.

Use this parameter for all connections that are not between a primary and mirror segment.

Value Range	Default	Set Classifications
number of lost keepalives	0	local, system, restart

tcp_keepalives_idle

Number of seconds between sending keepalives on an otherwise idle connection. A value of 0 uses the system default. If TCP_KEEPIDLE is not supported, this parameter must be 0.

Use this parameter for all connections that are not between a primary and mirror segment.

Value Range	Default	Set Classifications
number of seconds	0	local, system, restart

tcp_keepalives_interval

How many seconds to wait for a response to a keepalive before retransmitting. A value of 0 uses the system default. If TCP_KEEPINTVL is not supported, this parameter must be 0.

Use this parameter for all connections that are not between a primary and mirror segment.

Value Range	Default	Set Classifications
number of seconds	0	local, system, restart

temp_buffers

Sets the maximum memory, in blocks, to allow for temporary buffers by each database session. These are session-local buffers used only for access to temporary tables. The setting can be changed within individual sessions, but only up until the first use of temporary tables within a session. The cost of setting a large value in sessions that do not actually need a lot of temporary buffers is only a buffer descriptor for each block, or about 64 bytes, per increment. However if a buffer is actually used, an additional 32768 bytes will be consumed.

You can set this parameter to the number of 32K blocks (for example, `1024` to allow 32MB for buffers), or specify the maximum amount of memory to allow (for example `'48MB'` for 1536 blocks). The `gpconfig` utility and `SHOW` command report the maximum amount of memory allowed for temporary buffers.

Value Range	Default	Set Classifications
integer	1024 (32MB)	coordinator, session, reload

temp_tablespaces

Specifies tablespaces in which to create temporary objects (temp tables and indexes on temp tables) when a `CREATE` command does not explicitly specify a tablespace. These tablespaces can also include temporary files for purposes such as large data set sorting.

The value is a comma-separated list of tablespace names. When the list contains more than one tablespace name, WarehousePG chooses a random list member each time it creates a temporary object. An exception applies within a transaction, where successively created temporary objects are placed in successive tablespaces from the list. If the selected element of the list is an empty string, WarehousePG automatically uses the default tablespace of the current database instead.

When setting `temp_tablespaces` interactively, avoid specifying a nonexistent tablespace, or a tablespace for which the user does have `CREATE` privileges. For non-superusers, a superuser must `GRANT` them the `CREATE` privilege on the temp tablespace.. When using a previously set value (for example a value in `postgresql.conf`), nonexistent tablespaces are ignored, as are tablespaces for which the user lacks `CREATE` privilege.

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The default value is an empty string, which results in all temporary objects being created in the default tablespace of the current database.

See also default_tablespace.

Value Range	Default	Set Classifications
one or more tablespace names	unset	coordinator, session, reload

TimeZone

Sets the time zone for displaying and interpreting time stamps. The default is to use whatever the system environment specifies as the time zone. SeeDate/Time Keywords in the PostgreSQL documentation.

Value Range	Default	Set Classifications
time zone abbreviation		local, restart

timezone_abbreviations

Sets the collection of time zone abbreviations that will be accepted by the server for date time input. The default is `Default`, which is a collection that works in most of the world. `Australia` and `India`, and other collections can be defined for a particular installation. Possible values are names of configuration files stored in `$GPHOME/share/postgresql/timezonesets/`.

To configure WarehousePG to use a custom collection of timezones, copy the file that contains the timezone definitions to the directory `$GPHOME/share/postgresql/timezonesets/` on the WarehousePG coordinator and segment hosts. Then set value of the server configuration parameter `timezone_abbreviations` to the file. For example, to use a file `custom` that contains the default timezones and the WIB (Waktu Indonesia Barat) timezone.

1. Copy the file `Default` from the directory `$GPHOME/share/postgresql/timezonesets/` the file `custom`. Add the WIB timezone information from the file `Asia.txt` to the `custom`.
2. Copy the file `custom` to the directory `$GPHOME/share/postgresql/timezonesets/` on the WarehousePG coordinator and segment hosts.
3. Set value of the server configuration parameter `timezone_abbreviations` to `custom`.
4. Reload the server configuration file (`gpstop -u`).

Value Range	Default	Set Classifications
string	Default	coordinator, session, reload

track_activities

Enables the collection of information on the currently executing command of each session, along with the time when that command began execution. This parameter is `true` by default. Only superusers can change this setting. See the `pg_stat_activity` view.

> **Note** Even when enabled, this information is not visible to all users, only to superusers and the user owning the session being reported on, so it should not represent a security risk.

Value Range	Default	Set Classifications
Boolean	true	coordinator, session, reload, superuser

track_activity_query_size

Sets the maximum length limit for the query text stored in `query` column of the system catalog view *pg_stat_activity*. The minimum length is 1024 characters.

Value Range	Default	Set Classifications
integer	1024	local, system, restart

track_counts

Collects information about executing commands. Enables the collection of information on the currently executing command of each session, along with the time at which that command began execution.

Value Range	Default	Set Classifications
Boolean	true	coordinator, session, reload, superuser

track_wal_io_timing

Enables timing of WAL I/O calls. This parameter is disabled by default, as it repeatedly queries the operating system for the current time, which may cause significant overhead on some platforms. The viewpg_stat_wal displays WAL I/O timing information. Only superusers and users with the appropriate `SET` privilege can change this setting.

Value Range	Default	Set Classifications
Boolean	false	coordinator, session, reload

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transaction_isolation

Sets the current transaction's isolation level.

Value Range	Default	Set Classifications
read committed, serializable	read committed	coordinator, session, reload

transaction_read_only

Sets the current transaction's read-only status.

Value Range	Default	Set Classifications
Boolean	off	coordinator, session, reload

transaction_deferrable

For the current read-only serializable transaction, specifies whether to defer until it can be executed with no possible serialization failures.

Value Range	Default	Set Classifications
Boolean	value of `default_transaction_deferrable`	coordinator, session, reload

transform_null_equals

When on, expressions of the form expr = NULL (or NULL = expr) are treated as expr IS NULL, that is, they return true if expr evaluates to the null value, and false otherwise. The correct SQL-spec-compliant behavior of expr = NULL is to always return null (unknown).

Value Range	Default	Set Classifications
Boolean	off	coordinator, session, reload

unix_socket_directories

Specifies the directory of the UNIX-domain socket on which the server is to listen for connections from client applications. Multiple sockets can be created by listing multiple directories separated by commas.

> **Important** Do not change the value of this parameter. The default location is required for WarehousePG utilities.

Value Range	Default	Set Classifications
directory path	0777	local, system, restart

unix_socket_group

Sets the owning group of the UNIX-domain socket. By default this is an empty string, which uses the default group for the current user.

Value Range	Default	Set Classifications
UNIX group name	unset	local, system, restart

unix_socket_permissions

Sets the access permissions of the UNIX-domain socket. UNIX-domain sockets use the usual UNIX file system permission set. Note that for a UNIX-domain socket, only write permission matters.

Value Range	Default	Set Classifications
numeric UNIX file permission mode (as accepted by the *chmod* or *umask* commands)	0777	local, system, restart

update_process_title

Enables updating of the process title every time a new SQL command is received by the server. The process title is typically viewed by the `ps` command.

Value Range	Default	Set Classifications
Boolean	on	local, session, reload

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vacuum_cleanup_index_scale_factor

Specifies the fraction of the total number of heap tuples counted in the previous statistics collection that can be inserted without incurring an index scan at the `VACUUM` cleanup stage. The purpose of this parameter is to minimize unnecessary vacuum index scans. This setting currently applies to B-tree indexes only. When its value is 0, `VACUUM` cleanup never skips index scans.

If no tuples were deleted from the heap, B-tree indexes are still scanned at the `VACUUM` cleanup stage when at least one of the following conditions is met: the index statistics are stale, or the index contains deleted pages that can be recycled during cleanup. Index statistics are considered to be stale if the number of newly inserted tuples exceeds the `vacuum_cleanup_index_scale_factor` fraction of the total number of heap tuples detected by the previous statistics collection. The total number of heap tuples is stored in the index meta-page. Note that the meta-page does not include this data until `VACUUM` finds no dead tuples, so B-tree index scan at the cleanup stage can only be skipped if the second and subsequent `VACUUM` cycles detect no dead tuples.

Value Range	Default	Set Classifications
floating point 0 to 10000000000	0.1	local, session, reload

vacuum_cost_delay

The length of time that the process will sleep when the cost limit has been exceeded. 0 deactivates the cost-based vacuum delay feature.

Value Range	Default	Set Classifications
milliseconds < 0 (in multiples of 10)	0	local, session, reload

vacuum_cost_limit

The accumulated cost that will cause the vacuuming process to sleep.

Value Range	Default	Set Classifications
integer > 0	200	local, session, reload

vacuum_cost_page_dirty

The estimated cost charged when vacuum modifies a block that was previously clean. It represents the extra I/O required to flush the dirty block out to disk again.

Value Range	Default	Set Classifications
integer > 0	20	local, session, reload

vacuum_cost_page_hit

The estimated cost for vacuuming a buffer found in the shared buffer cache. It represents the cost to lock the buffer pool, lookup the shared hash table and scan the content of the page.

Value Range	Default	Set Classifications
integer > 0	1	local, session, reload

vacuum_cost_page_miss

The estimated cost for vacuuming a buffer that has to be read from disk. This represents the effort to lock the buffer pool, lookup the shared hash table, read the desired block in from the disk and scan its content.

Value Range	Default	Set Classifications
integer > 0	2	local, session, reload

vacuum_freeze_min_age

Specifies the cutoff age (in transactions) that `VACUUM` should use to decide whether to replace transaction IDs with *FrozenXID* while scanning a table.

For information about `VACUUM` and transaction ID management, see "Managing Data" in the *WarehousePG Administrator Guide* and the PostgreSQL documentation.

Value Range	Default	Set Classifications
integer 0-100000000000	50000000	local, session, reload

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validate_previous_free_tid

Enables a test that validates the free tuple ID (TID) list. The list is maintained and used by WarehousePG. WarehousePG determines the validity of the free TID list by ensuring the previous free TID of the current free tuple is a valid free tuple. The default value is `true`, enable the test.

If WarehousePG detects a corruption in the free TID list, the free TID list is rebuilt, a warning is logged, and a warning is returned by queries for which the check failed. WarehousePG attempts to run the queries.

> **Note** If a warning is returned, please contact Support.

Value Range	Default	Set Classifications
Boolean	true	coordinator, session, reload

verify_gpfdists_cert

When a WarehousePG external table is defined with the `gpfdists` protocol to use SSL security, this parameter controls whether SSL certificate authentication is enabled.

Regardless of the setting of this server configuration parameter, WarehousePG always encrypts data that you read from or write to an external table that specifies the `gpfdists` protocol.

The default is `true`, SSL certificate authentication is enabled when WarehousePG communicates with the `gpfdist` utility to either read data from or write data to an external data source.

The value `false` deactivates SSL certificate authentication. These SSL exceptions are ignored:

- The self-signed SSL certificate that is used by `gpfdist` is not trusted by WarehousePG.
- The host name contained in the SSL certificate does not match the host name that is running `gpfdist`.

When you set `verify_gpfdists_cert` to `false`, the CA certification file is not required for WarehousePG segments.

You can set the value to `false` to deactivate authentication when testing the communication between the WarehousePG external table and the `gpfdist` utility that is serving the external data.

> **Caution** Deactivating SSL certificate authentication exposes a security risk by not validating the `gpfdists` SSL certificate.

For information about the `gpfdists` protocol and how this setting affects the certificate files required on WarehousePG segments, see gpfdists:// Protocol. For information about running the `gpfdist` utility, see gpfdist.

Value Range	Default	Set Classifications
Boolean	true	coordinator, session, reload

vmem_process_interrupt

Enables checking for interrupts before reserving vmem memory for a query during WarehousePG query execution. Before reserving further vmem for a query, check if the current session for the query has a pending query cancellation or other pending interrupts. This ensures more responsive interrupt processing, including query cancellation requests. The default is `off`.

Value Range	Default	Set Classifications
Boolean	off	coordinator, session, reload

wait_for_replication_threshold

When WarehousePG segment mirroring is enabled, specifies the maximum amount of Write-Ahead Logging (WAL)-based records (in KB) written by a transaction on the primary segment instance before the records are written to the mirror segment instance for replication. As the default, WarehousePG writes the records to the mirror segment instance when a checkpoint occurs or the `wait_for_replication_threshold` value is reached.

A value of 0 deactivates the check for the amount of records. The records are written to the mirror segment instance only after a checkpoint occurs.

If you set the value to 0, database performance issues might occur under heavy loads that perform long transactions that do not perform a checkpoint operation.

Value Range	Default	Set Classifications
0 - MAX-INT / 1024	1024	coordinator, system, reload

wal_keep_size

Specifies the minimum size of past log file segments kept in the `pg_wal` directory, in case a standby coordinator or mirror segment instance needs to fetch them for streaming replication. If a standby coordinator or mirror segment instance connected to the sending server falls behind by more than `wal_keep_size` megabytes, the sending server might remove a WAL segment still needed by the standby coordinator or mirror segment instance, in which case the replication connection will be terminated.

This sets only the minimum size of segments retained in `pg_wal`; the system might need to retain more segments for WAL archival or to recover from a checkpoint. If `wal_keep_size` is zero (the default), the number of old WAL segments available to mirror servers is a function of the location of replication slot's `restart_lsn` and `max_slot_wal_keep_size` parameters, as well as the status of WAL archiving.

If this value is specified without units, it is taken as megabytes.

Value Range	Default	Set Classifications
integer	5 times the default size of the write-ahead log file	coordinator, system, reload, superuser

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wal_receiver_status_interval

For WarehousePG coordinator mirroring, sets the interval in seconds between `walreceiver` process status messages that are sent to the active coordinator. Under heavy loads, the time might be longer.

The value of wal_sender_timeout controls the time that the `walsender` process waits for a `walreceiver` message.

Value Range	Default	Set Classifications
integer 0- INT_MAX/1000	10 sec	coordinator, system, reload, superuser

work_mem

Sets the maximum amount of memory to be used by a query operation (such as a sort or hash table) before writing to temporary disk files. If this value is specified without units, it is taken as kilobytes. The default value is 32 MB. Note that for a complex query, several sort or hash operations might be running in parallel; each operation will be allowed to use as much memory as this value specifies before it starts to write data into temporary files. In addition, several running sessions may be performing such operations concurrently. Therefore, the total memory used could be many times the value of `work_mem`; keep this fact in mind when choosing the value for this parameter. Sort operations are used for `ORDER BY`, `DISTINCT`, and merge joins. Hash tables are used in hash joins, hash-based aggregation, and hash-based processing of `IN` subqueries. Apart from sorting and hashing, bitmap index scans also rely on `work_mem`. Operations relying on tuplestores such as function scans, CTEs, PL/pgSQL and administration UDFs also rely on `work_mem`.

Apart from assigning memory to specific execution operators, setting `work_mem` also influences certain query plans over others, when the Postgres-based planner is used as the optimizer.

`work_mem` is a distinct memory management concept that does not interact with resource queue or resource group memory controls, which are imposed at the query level.

Value Range	Default	Set Classifications
number of kilobytes	32MB	coordinator, session, reload

writable_external_table_bufsize

Size of the buffer that WarehousePG uses for network communication, such as the `gpfdist` utility and external web tables (that use http). Valid units are `KB` (as in `128KB`), `MB`, `GB`, and `TB`. WarehousePG stores data in the buffer before writing the data out. For information about `gpfdist`, see the *WarehousePG Utility Guide*.

Value Range	Default	Set Classifications
integer 32 - 131072 (32KB - 128MB)	64	local, session, reload

xid_stop_limit

The number of transaction IDs prior to the ID where transaction ID wraparound occurs. When this limit is reached, WarehousePG stops creating new transactions to avoid data loss due to transaction ID wraparound.

Value Range	Default	Set Classifications
integer 10000000 - INT_MAX	100000000	local, system, restart

xid_warn_limit

The number of transaction IDs prior to the limit specified by xid_stop_limit. When WarehousePG reaches this limit, it issues a warning to perform a VACUUM operation to avoid data loss due to transaction ID wraparound.

Value Range	Default	Set Classifications
integer 10000000 - INT_MAX	500000000	local, system, restart

xmlbinary

Specifies how binary values are encoded in XML data. For example, when `bytea` values are converted to XML. The binary data can be converted to either base64 encoding or hexadecimal encoding. The default is base64.

The parameter can be set for a database system, an individual database, or a session.

Value Range	Default	Set Classifications
base64, hex	base64	coordinator, session, reload

xmloption

Specifies whether XML data is to be considered as an XML document (`document`) or XML content fragment (`content`) for operations that perform implicit parsing and serialization. The default is `content`.

This parameter affects the validation performed by `xml_is_well_formed()`. If the value is `document`, the function checks for a well-formed XML document. If the value is `content`, the function checks for a well-formed XML content fragment.

> **Note** An XML document that contains a document type declaration (DTD) is not considered a valid XML content fragment. If `xmloption` set to `content`, XML that contains a DTD is not considered valid XML.

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To cast a character string that contains a DTD to the `xml` data type, use the `xmlparse` function with the `document` keyword, or change the `xmloption` value to `document`.

The parameter can be set for a database system, an individual database, or a session. The SQL command to set this option for a session is also available in WarehousePG.

```
SET XML OPTION { DOCUMENT | CONTENT }
```

Value Range	Default	Set Classifications
document, content	content	coordinator, session, reload

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7.6.2 Parameter Categories

Configuration parameters affect categories of server behaviors, such as resource consumption, query tuning, and authentication. The following topics describe WarehousePG configuration parameter categories.

- Connection and Authentication Parameters
- System Resource Consumption Parameters
- GPORCA Parameters
- Query Tuning Parameters
- Error Reporting and Logging Parameters
- Runtime Statistics Collection Parameters
- Automatic Vacuum Parameters
- Automatic Statistics Collection Parameters
- Client Connection Default Parameters
- Lock Management Parameters
- Resource Management Parameters (Resource Queues)
- Resource Management Parameters (Resource Groups)
- External Table Parameters
- Database Table Parameters
- Past Version Compatibility Parameters
- WarehousePG cluster Configuration Parameters
- WarehousePG Mirroring Parameters for Coordinator and Segments
- WarehousePG PL/Java Parameters

Connection and Authentication Parameters

These parameters control how clients connect and authenticate to WarehousePG.

Connection Parameters

- client_connection_check_interval
- gp_connection_send_timeout
- gp_dispatch_keepalives_count
- gp_dispatch_keepalives_idle
- gp_dispatch_keepalives_interval
- gp_postmaster_address_family
- gp_vmem_idle_resource_timeout
- listen_addresses
- max_connections
- max_prepared_transactions
- superuser_reserved_connections
- tcp_keepalives_count
- tcp_keepalives_idle
- tcp_keepalives_interval
- unix_socket_directories
- unix_socket_group
- unix_socket_permissions

Security and Authentication Parameters

- authentication_timeout
- db_user_namespace
- krb_caseins_users
- krb_server_keyfile
- password_encryption
- row_security
- ssl
- ssl_ciphers

System Resource Consumption Parameters

These parameters set the limits for system resources consumed by WarehousePG.

Memory Consumption Parameters

These parameters control system memory usage.

- gp_vmem_idle_resource_timeout
- gp_vmem_protect_limit (resource queue-based resource management)
- gp_vmem_protect_segworker_cache_limit
- gp_workfile_limit_files_per_query
- gp_workfile_limit_per_query
- gp_workfile_limit_per_segment
- maintenance_work_mem
- max_stack_depth
- shared_buffers
- temp_buffers
- work_mem

OS Resource Parameters

- max_files_per_process
- shared_preload_libraries

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Cost-Based Vacuum Delay Parameters

> **Caution** Do not use cost-based vacuum delay because it runs asynchronously among the segment instances. The vacuum cost limit and delay is invoked at the segment level without taking into account the state of the entire WarehousePG cluster

You can configure the execution cost of `VACUUM` and `ANALYZE` commands to reduce the I/O impact on concurrent database activity. When the accumulated cost of I/O operations reaches the limit, the process performing the operation sleeps for a while, Then resets the counter and continues execution

- vacuum_cost_delay
- vacuum_cost_limit
- vacuum_cost_page_dirty
- vacuum_cost_page_hit
- vacuum_cost_page_miss

Transaction ID Management Parameters

- xid_stop_limit
- xid_warn_limit

Other Parameters

- gp_max_parallel_cursors

GPORCA Parameters

These parameters control the usage of GPORCA by WarehousePG. For information about GPORCA, seeAbout GPORCA in the *WarehousePG Administrator Guide*.

- gp_enable_relsize_collection
- optimizer
- optimizer_analyze_root_partition
- optimizer_array_expansion_threshold
- optimizer_control
- optimizer_cost_model
- optimizer_cte_inlining_bound
- optimizer_dpe_stats
- optimizer_discard_redistribute_hashjoin
- optimizer_enable_associativity
- optimizer_enable_dml
- optimizer_enable_dynamicindexonlyscan
- optimizer_enable_foreign_table
- optimizer_enable_indexonlyscan
- optimizer_enable_coordinator_only_queries
- optimizer_enable_multiple_distinct_aggs
- optimizer_enable_orderedagg
- optimizer_enable_push_join_below_union_all
- optimizer_enable_replicated_table
- optimizer_enable_right_outer_join
- optimizer_force_agg_skew_avoidance
- optimizer_force_comprehensive_join_implementation
- optimizer_force_multistage_agg
- optimizer_force_three_stage_scalar_dqa
- optimizer_join_arity_for_associativity_commutativity
- optimizer_join_order
- optimizer_join_order_threshold
- optimizer_mdcache_size
- optimizer_metadata_caching
- optimizer_parallel_union
- optimizer_penalize_broadcast_threshold
- optimizer_penalize_skew
- optimizer_print_missing_stats
- optimizer_print_optimization_stats
- optimizer_skew_factor
- optimizer_sort_factor
- optimizer_use_gpdb_allocators
- optimizer_xform_bind_threshold

Query Tuning Parameters

These parameters control aspects of SQL query processing such as query operators and operator settings and statistics sampling.

Postgres-based planner Control Parameters

The following parameters control the types of plan operations the Postgres-based planner can use. Enable or deactivate plan operations to force the Postgres-based planner to choose a different plan. This is useful for testing and comparing query performance using different plan types.

- enable_bitmapscan
- enable_groupagg
- enable_hashagg
- enable_hashjoin
- enable_indexscan
- enable_mergejoin
- enable_nestloop
- enable_partition_pruning
- enable_seqscan
- enable_sort
- enable_tidscan
- gp_eager_two_phase_agg
- gp_enable_agg_distinct

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- gp_enable_agg_distinct_pruning
- gp_enable_direct_dispatch
- gp_enable_fast_sri
- gp_enable_groupext_distinct_gather
- gp_enable_groupext_distinct_pruning
- gp_enable_multiphase_agg
- gp_enable_predicate_propagation
- gp_enable_preunique
- gp_enable_relsize_collection
- gp_enable_sort_limit

Postgres-based planner Costing Parameters

> **Caution** Do not adjust these query costing parameters. They are tuned to reflect WarehousePG hardware configurations and typical workloads. All of these parameters are related. Changing one without changing the others can have adverse affects on performance.

- cpu_index_tuple_cost
- cpu_operator_cost
- cpu_tuple_cost
- cursor_tuple_fraction
- effective_cache_size
- gp_motion_cost_per_row
- gp_segments_for_planner
- random_page_cost
- seq_page_cost

Database Statistics Sampling Parameters

These parameters adjust the amount of data sampled by an `ANALYZE` operation. Adjusting these parameters affects statistics collection system-wide. You can configure statistics collection on particular tables and columns by using the `ALTER TABLE SET STATISTICS` clause.

- default_statistics_target

Sort Operator Configuration Parameters

- gp_enable_sort_limit

Aggregate Operator Configuration Parameters

- gp_enable_agg_distinct
- gp_enable_agg_distinct_pruning
- gp_enable_multiphase_agg
- gp_enable_preunique
- gp_enable_groupext_distinct_gather
- gp_enable_groupext_distinct_pruning
- gp_workfile_compression

Join Operator Configuration Parameters

- join_collapse_limit
- gp_adjust_selectivity_for_outerjoins
- gp_hashjoin_tuples_per_bucket
- gp_workfile_compression

Other Postgres-based planner Configuration Parameters

- from_collapse_limit
- gp_enable_predicate_propagation
- gp_max_plan_size
- gp_statistics_pullup_from_child_partition
- gp_statistics_use_fkeys

Query Plan Execution

Control the query plan execution.

- gp_max_slices
- gp_max_system_slices
- plan_cache_mode

JIT Configuration Parameters

- gp_explain_jit
- jit
- jit_above_cost
- jit_debugging_support
- jit_dump_bitcode
- jit_expressions
- jit_inline_above_cost
- jit_optimize_above_cost
- jit_profiling_support
- jit_provider
- jit_tuple_deforming
- optimizer_jit_above_cost

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- optimizer_jit_inline_above_cost
- optimizer_jit_optimize_above_cost

Error Reporting and Logging Parameters

These configuration parameters control WarehousePG logging.

Log Rotation

- log_rotation_age
- log_rotation_size
- log_truncate_on_rotation

When to Log

- client_min_messages
- gp_interconnect_debug_retry_interval
- log_error_verbosity
- log_file_mode
- log_min_duration_statement
- log_min_error_statement
- log_min_messages
- optimizer_minidump

What to Log

- debug_pretty_print
- debug_print_parse
- debug_print_plan
- debug_print_prelim_plan
- debug_print_rewritten
- debug_print_slice_table
- debug_shareinput_xslice
- log_autostats
- log_connections
- log_directory
- log_disconnections
- log_dispatch_stats
- log_duration
- log_executor_stats
- log_hostname
- gp_log_endpoints
- gp_log_interconnect
- gp_print_create_gang_time
- log_parser_stats
- log_planner_stats
- log_statement
- log_statement_stats
- log_timezone
- gp_debug_linger
- gp_log_format
- gp_reraise_signal

Automatic Vacuum Parameters

These parameters pertain to auto-vacuuming databases.

- autovacuum
- autovacuum_analyze_scale_factor
- autovacuum_analyze_threshold
- autovacuum_freeze_max_age
- autovacuum_max_workers
- autovacuum_multixact_freeze_max_age
- autovacuum_naptime
- autovacuum_vacuum_cost_delay
- autovacuum_vacuum_cost_limit
- autovacuum_vacuum_scale_factor
- autovacuum_vacuum_threshold
- gp_autovacuum_scope

Runtime Statistics Collection Parameters

These parameters control the server statistics collection feature. When statistics collection is enabled, you can access the statistics data using the *pg_stat* family of system catalog views.

- stats_queue_level
- track_activities
- track_counts
- update_process_title

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Automatic Statistics Collection Parameters

When automatic statistics collection is enabled, you can run `ANALYZE` automatically in the same transaction as an `INSERT`, `UPDATE`, `DELETE`, `COPY` or `CREATE TABLE...AS SELECT` statement when a certain threshold of rows is affected (`on_change`), or when a newly generated table has no statistics (`on_no_stats`). To enable this feature, set the following server configuration parameters in your WarehousePG coordinator `postgresql.conf` file and restart WarehousePG:

- gp_autostats_allow_nonowner
- gp_autostats_lock_wait
- gp_autostats_mode
- gp_autostats_mode_in_functions
- gp_autostats_on_change_threshold
- log_autostats

> **Caution** Depending on the specific nature of your database operations, automatic statistics collection can have a negative performance impact. Carefully evaluate whether the default setting of `on_no_stats` is appropriate for your system.

Client Connection Default Parameters

These configuration parameters set defaults that are used for client connections.

Statement Behavior Parameters

- check_function_bodies
- default_tablespace
- default_transaction_deferrable
- default_transaction_isolation
- default_transaction_read_only
- search_path
- gin_pending_list_limit
- statement_timeout
- temp_tablespaces
- vacuum_cleanup_index_scale_factor
- vacuum_freeze_min_age

Locale and Formatting Parameters

- client_encoding
- DateStyle
- extra_float_digits
- IntervalStyle
- lc_collate
- lc_ctype
- lc_messages
- lc_monetary
- lc_numeric
- lc_time
- TimeZone

Other Client Default Parameters

- dynamic_library_path
- explain_pretty_print
- local_preload_libraries

Lock Management Parameters

These configuration parameters set limits for locks and deadlocks.

- deadlock_timeout
- gp_enable global_deadlock_detector[gp_global_deadlock_detector_period](guc-list.html#gp_enable global_deadlock_detector](guc-list.html)[gp_global_deadlock_detector_period)
- lock_timeout
- max_locks_per_transaction

Resource Management Parameters (Resource Queues)

The following configuration parameters configure the WarehousePG resource management feature (resource queues), query prioritization, memory utilization and concurrency control.

- gp_resqueue_memory_policy
- gp_resqueue_priority
- gp_resqueue_priority_cpucores_per_segment
- gp_resqueue_priority_sweeper_interval
- gp_vmem_idle_resource_timeout
- gp_vmem_protect_limit
- gp_vmem_protect_segworker_cache_limit
- max_resource_queues
- max_resource_portals_per_transaction
- max_statement_mem
- resource_cleanup_gangs_on_wait
- resource_select_only
- runaway_detector_activation_percent
- statement_mem
- stats_queue_level
- vmem_process_interrupt

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Resource Management Parameters (Resource Groups)

The following parameters configure the WarehousePG resource group workload management feature.

- gp_resgroup_memory_policy
- gp_resgroup_memory_query_fixed_mem
- gp_resource_group_bypass
- gp_resource_group_bypass_catalog_query
- gp_resource_group_bypass_direct_dispatch
- gp_resource_group_cgroup_parent
- gp_resource_group_cpu_limit
- gp_resource_group_cpu_priority
- gp_resource_group_move_timeout
- gp_resource_group_queuing_timeout
- gp_resource_manager
- gp_vmem_idle_resource_timeout
- gp_vmem_protect_segworker_cache_limit
- max_statement_mem
- runaway_detector_activation_percent
- statement_mem
- vmem_process_interrupt

External Table Parameters

The following parameters configure the external tables feature of WarehousePG.

- gp_external_enable_exec
- gp_external_enable_filter_pushdown
- gp_external_max_segs
- gp_initial_bad_row_limit
- gp_reject_percent_threshold
- gpfdist_retry_timeout
- readable_external_table_timeout
- writable_external_table_bufsize
- verify_gpfdists_cert

Database Table Parameters

The following parameter configures default option settings for WarehousePG tables.

- default_table_access_method
- gp_create_table_random_default_distribution
- gp_default_storage_options
- gp_enable_segment_copy_checking
- gp_use_legacy_hashops

Append-Optimized Table Parameters

The following parameters configure the append-optimized tables feature of WarehousePG.

- gp_appendonly_compaction
- gp_appendonly_compaction_threshold
- validate_previous_free_tid

Past Version Compatibility Parameters

The following parameters provide compatibility with older PostgreSQL and WarehousePG versions. You do not need to change these parameters in WarehousePG.

PostgreSQL

- array_nulls
- backslash_quote
- escape_string_warning
- gp_quicklz_fallback
- quote_all_identifiers
- standard_conforming_strings
- transform_null_equals

WarehousePG

- gp_ignore_error_table

WarehousePG cluster Configuration Parameters

The parameters in this topic control the configuration of the WarehousePG cluster and its components: segments, coordinator, distributed transaction manager, coordinator mirror, and interconnect.

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Interconnect Configuration Parameters

- gp_interconnect_address_type
- gp_interconnect_fc_method
- gp_interconnect_proxy_addresses
- gp_interconnect_queue_depth
- gp_interconnect_setup_timeout
- gp_interconnect_snd_queue_depth
- gp_interconnect_transmit_timeout
- gp_interconnect_type
- gp_max_packet_size

> **Note** WarehousePG supports only the UDPIFC (default) and TCP interconnect types.

Dispatch Configuration Parameters

- gp_cached_segworkers_threshold
- gp_enable_direct_dispatch
- gp_segment_connect_timeout
- gp_set_proc_affinity

Fault Operation Parameters

- gp_set_read_only
- gp_fts_probe_interval
- gp_fts_probe_retries
- gp_fts_probe_timeout
- gp_fts_replication_attempt_count
- gp_log_fts

Distributed Transaction Management Parameters

- gp_max_local_distributed_cache

Read-Only Parameters

- gp_command_count
- gp_content
- gp_dbid
- gp_retrieve_conn
- gp_role
- gp_session_id
- gp_server_version
- gp_server_version_num

WarehousePG Mirroring Parameters for Coordinator and Segments

These parameters control the configuration of the replication between WarehousePG primary coordinator and standby coordinator.

- checkpoint_completion_target
- checkpoint_flush_after
- checkpoint_timeout
- checkpoint_warning
- max_slot_wal_keep_size
- max_wal_size
- min_wal_size
- repl_catchup_within_range
- replication_timeout
- track_wal_io_timing
- wait_for_replication_threshold
- wal_buffers
- wal_compression
- wal_keep_size
- wal_receiver_status_interval

WarehousePG PL/Java Parameters

The parameters in this topic control the configuration of the WarehousePG PL/Java language.

- pljava_classpath
- pljava_classpath_insecure
- pljava_statement_cache_size
- pljava_release_lingering_savepoints
- pljava_vmoptions

XML Data Parameters

The parameters in this topic control the configuration of the WarehousePG XML data type.

- xmlbinary
- xmloption

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7.7 WarehousePG cluster utility guide

Reference information for WarehousePG utility programs.

- About the WarehousePG Utilities
  General information about using the WarehousePG utility programs.
- Utility Reference
  The command-line utilities provided with WarehousePG.
- Additional Supplied Utilities
  Additional programs available in the WarehousePG installation.

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7.7.1 About the WarehousePG Utilities

General information about using the WarehousePG utility programs.

Referencing IP Addresses

When you reference IPv6 addresses in WarehousePG utility programs, or when you use numeric IP addresses instead of hostnames in any management utility, always enclose the IP address in brackets. When specifying an IP address at the command line, the best practice is to escape any brackets or enclose them in single quotes. For example, use either:

```
\[2620:0:170:610::11\]
```

Or:

```
'[2620:0:170:610::11]'
```

Running Backend Server Programs

WarehousePG has modified certain PostgreSQL backend server programs to handle the parallelism and distribution of a WarehousePG cluster. You access these programs only through the WarehousePG management tools and utilities. *Do not run these programs directly.*

The following table identifies certain PostgreSQL backend server programs and the WarehousePG utility command to run instead.

PostgreSQL Program Name	Description	Use Instead
`initdb`	This program is called by `gpinitsystem` when initializing a WarehousePG cluster. It is used internally to create the individual segment instances and the coordinator instance.	gpinitsystem
`ipcclean`	Not used in WarehousePG	N/A
`pg_basebackup`	This program makes a binary copy of a single database instance. WarehousePG uses it for tasks such as creating a standby coordinator instance, or recovering a mirror segment when a full copy is needed. Do not use this utility to back up WarehousePG segment instances because it does not produce MPP-consistent backups.	gpinitstandby, `[gprecoverseg](ref/gprecoverseg.html)`
`pg_controldata`	Not used in WarehousePG	gpstate
`pg_ctl`	This program is called by `gpstart` and `gpstop` when starting or stopping a WarehousePG cluster. It is used internally to stop and start the individual segment instances and the coordinator instance in parallel and with the correct options.	gpstart, gpstop
`pg_resetwal`	DO NOT USE > **Caution** This program might cause data loss or cause data to become unavailable. If this program is used, the WarehousePG cluster is not supported. Thecluster must be reinitialized and restoredby the customer.	N/A
`postgres`	The `postgres` executable is the actual PostgreSQL server process that processes queries.	The main `postgres` process (postmaster) creates other `postgres` subprocesses and `postgres` session as needed to handle client connections.
`postmaster`	`postmaster` starts the `postgres` database server listener process that accepts client connections. In WarehousePG, a `postgres` database listener process runs on the WarehousePG coordinator Instance and on each Segment Instance.	In WarehousePG, you use gpstart and gpstop to start all postmasters (`postgres` processes) in the system at once in the correct order and with the correct options.

Parent topic: WarehousePG Utility Guide

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7.7.2 Utility Reference

The command-line utilities provided with WarehousePG.

WarehousePG uses the standard PostgreSQL client and server programs and provides additional management utilities for administering a distributed WarehousePG DBMS.

Several utilities are installed when you install the WarehousePG server. These utilities reside in `$GPHOME/bin`.

Other utilities such as clients and backup/restore may be found at Warehouse PG Github Repo

WarehousePG provides the following utility programs. Superscripts identify those utilities that require separate downloads, as well as those utilities that are also installed with the Client and Loader Tools Packages. (See the Note following the table.) All utilities are installed when you install the WarehousePG server, unless specifically identified by a superscript.

- analyzedb
- clusterdb
- createdb[1]
- createuser[1]
- dropdb[1]
- dropuser[1]
- gpactivatestandby
- gpaddmirrors
- gpbackup[2]
- gpcheckcat
- gpcheckperf
- gpconfig
- gpdeletesystem
- gpexpand
- gpfdist[1]
- gpinitstandby
- gpinitsystem
- gpload[1]
- gplogfilter
- gpmovemirrors
- gprecoverseg
- gpreload
- gprestore[2]
- gpssh
- gpssh-exkeys
- gpstart
- gpstate
- gpstop
- gpsync
- pg_config
- pg_dump[1]
- pg_dumpall[1]
- pg_restore
- pgbouncer
- pgbouncer.ini
- pgbouncer-admin
- psql[1]
- reindexdb
- vacuumdb

> **Note**
>
> [1] The utility program is also installed with the **WarehousePG Client and Loader Tools Package**
>
> [2] The utility program can be obtained from the **WarehousePG Backup and Restore**

Additional utilities may be found at Warehouse PG Github Org Repo

Parent topic: WarehousePG Utility Guide

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7.7.2.1 analyzedb

A utility that performs `ANALYZE` operations on tables incrementally and concurrently. For append optimized tables, analyzedb updates statistics only if the statistics are not current.

Synopsis

```
analyzedb -d <dbname>
   { -s <schema>  |
   { -t <schema>.<table>
     [ -i <col1>[,<col2>, ...] |
       -x <col1>[,<col2>, ...] ] } |
     { -f | --file} <config-file> }
   [ -l | --list ]
   [ --gen_profile_only ]
   [ -p <parallel-level> ]
   [ --full ]
   [ --skip_root_stats ]
   [ --skip_orca_root_stats ]
   [ -v | --verbose ]
   [ -a ]
   [ --skip-locked ]

analyzedb { --clean_last | --clean_all }
analyzedb --version
analyzedb { -? | -h | --help }
```

Description

The analyzedb utility updates statistics on table data for the specified tables in a WarehousePG incrementally and concurrently.

While performing ANALYZE operations, analyzedb creates a snapshot of the table metadata and stores it on disk on the coordinator host. An `ANALYZE` operation is performed only if the table has been modified. If a table or partition has not been modified since the last time it was analyzed, analyzedb automatically skips the table or partition because it already contains up-to-date statistics.

- For append optimized tables, analyzedb updates statistics incrementally, if the statistics are not current. For example, if table data is changed after statistics were collected for the table. If there are no statistics for the table, statistics are collected.
- For heap tables, statistics are always updated.

Specify the `--full` option to update append-optimized table statistics even if the table statistics are current.

By default, analyzedb creates a maximum of 5 concurrent sessions to analyze tables in parallel. For each session, analyzedb issues an ANALYZE command to the database and specifies different table names. The `-p` option controls the maximum number of concurrent sessions.

Partitioned Append-Optimized Tables

For a partitioned, append-optimized table, analyzedb checks the root partitioned table and the leaf partitions. If needed, the utility updates statistics for non-current partitions and the root partition. For information about how statistics are collected for partitioned tables, see ANALYZE.

`analyzedb` must sample additional partitions within a partitioned table when it encounters a stale partition, even when statistics are already collected. It is recomended that you run `analyzedb` on the root partition any time that you add a new partition(s) to a partitioned table. This operation both analyzes the leaf partitions in parallel and merges any updated statistics into the root partition.

Notes

The analyzedb utility updates append optimized table statistics if the table has been modified by DML or DDL commands, including INSERT, DELETE, UPDATE, CREATE TABLE, ALTER TABLE and TRUNCATE. The utility determines if a table has been modified by comparing catalog metadata of tables with the previous snapshot of metadata taken during a previous analyzedb operation. The snapshots of table metadata are stored as state files in the directory `db_analyze/<db_name>/<timestamp>` in the WarehousePG coordinator data directory.

The utility preserves old snapshot information from the past 8 days, and the 3 most recent state directories regardless of age, while all other directories are automatically removed. You can also specify the `--clean_last` or `--clean_all` option to remove state files generated by analyzedb.

If you do not specify a table, set of tables, or schema, the analyzedb utility collects the statistics as needed on all system catalog tables and user-defined tables in the database.

External tables are not affected by analyzedb.

Table names that contain spaces are not supported.

Running the `ANALYZE` command on a table, not using the `analyzedb` utility, does not update the table metadata that the `analyzedb` utility uses to determine whether table statistics are up to date.

Options

--clean_last Remove the state files generated by last analyzedb operation. All other options except -d are ignored.

--clean_all Remove all the state files generated by analyzedb. All other options except -d are ignored.

-d dbname Specifies the name of the database that contains the tables to be analyzed. If this option is not specified, the database name is read from the environment variable `PGDATABASE`. If `PGDATABASE` is not set, the user name specified for the connection is used.

-f config-file | --file config-file Text file that contains a list of tables to be analyzed. A relative file path from current directory can be specified.

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The file lists one table per line. Table names must be qualified with a schema name. Optionally, a list of columns can be specified using the -i or -x. No other options are allowed in the file. Other options such as `--full` must be specified on the command line.

Only one of the options can be used to specify the files to be analyzed: `-f` or `--file`, `-t`, or `-s`.

When performing ANALYZE operations on multiple tables, analyzedb creates concurrent sessions to analyze tables in parallel. The `-p` option controls the maximum number of concurrent sessions.

In the following example, the first line performs an ANALYZE operation on the table `public.nation`, the second line performs an ANALYZE operation only on the columns `l_shipdate` and `l_receiptdate` in the table `public.lineitem`.

```
public.nation
public.lineitem -i l_shipdate,l_receiptdate
```

--full Perform an ANALYZE operation on all the specified tables. The operation is performed even if the statistics are up to date.

--gen_profile_only Update the `analyzedb` snapshot of table statistics information without performing any `ANALYZE` operations. If other options specify tables or a schema, the utility updates the snapshot information only for the specified tables.

Specify this option if the `ANALYZE` command was run on database tables and you want to update the `analyzedb` snapshot for the tables.

-i col1,col2, ... Optional. Must be specified with the -t option. For the table specified with the -t option, collect statistics only for the specified columns.

Only -i, or -x can be specified. Both options cannot be specified.

-l | --list Lists the tables that would have been analyzed with the specified options. The ANALYZE operations are not performed.

-p parallel-level The number of tables that are analyzed in parallel. parallel level can be an integer between 1 and 10, inclusive. Default value is 5.

--skip_root_stats This option is no longer used, you may remove it from your scripts.

`--skip_orca_root_stats`

> **Note** Do not use this option if GPORCA is enabled.

Use this option if you find that `ANALYZE ROOTPARTITION` commands take a very long time to complete.

> **Caution** After you run `analyzedb` with this option, subsequent `analyzedb` executions will not update root partition statistics except when changes have been made to the table.

-s schema Specify a schema to analyze. All tables in the schema will be analyzed. Only a single schema name can be specified on the command line.

Only one of the options can be used to specify the files to be analyzed: `-f` or `--file`, `-t`, or `-s`.

-t schema.table Collect statistics only on schema.table. The table name must be qualified with a schema name. Only a single table name can be specified on the command line. You can specify the `-f` option to specify multiple tables in a file or the `-s` option to specify all the tables in a schema.

Only one of these options can be used to specify the files to be analyzed: `-f` or `--file`, `-t`, or `-s`.

-x col1,col2, ... Optional. Must be specified with the -t option. For the table specified with the -t option, exclude statistics collection for the specified columns. Statistics are collected only on the columns that are not listed.

Only -i, or -x can be specified. Both options cannot be specified.

-a Quiet mode. Do not prompt for user confirmation.

--skip-locked Skip relations that cannot be immediately locked.

-h | -? | --help Displays the online help.

-v | --verbose If specified, sets the logging level to verbose to write additional information the log file and to the command line during command execution. The information includes a list of all the tables to be analyzed (including leaf partitions of partitioned tables). Output also includes the duration of each `ANALYZE` operation.

--version Displays the version of this utility.

Examples

An example that collects statistics only on a set of table columns. In the database `mytest`, collect statistics on the columns `shipdate` and `receiptdate` in the table `public.orders`:

```
analyzedb -d mytest -t public.orders -i shipdate,receiptdate
```

An example that collects statistics on a table and exclude a set of columns. In the database `mytest`, collect statistics on the table `public.foo`, and do not collect statistics on the columns `bar` and `test2`.

```
analyzedb -d mytest -t public.foo -x bar,test2
```

An example that specifies a file that contains a list of tables. This command collect statistics on the tables listed in the file `analyze-tables` in the database named `mytest`.

```
analyzedb -d mytest -f analyze-tables
```

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If you do not specify a table, set of tables, or schema, the analyzedb utility collects the statistics as needed on all catalog tables and user-defined tables in the specified database. This command refreshes table statistics on the system catalog tables and user-defined tables in the database `mytest`.

```
analyzedb -d mytest
```

You can create a PL/Python function to run the `analyzedb` utility as a WarehousePG function. This example `CREATE FUNCTION` command creates a user defined PL/Python function that runs the `analyzedb` utility and displays output on the command line. Specify `analyzedb` options as the function parameter.

```
CREATE OR REPLACE FUNCTION analyzedb(params TEXT)
  RETURNS VOID AS
$BODY$
    import subprocess
    cmd = ['analyzedb', '-a' ] + params.split()
    p = subprocess.Popen(cmd, stdout=subprocess.PIPE, stderr=subprocess.STDOUT)

    # verbose output of process
    for line in iter(p.stdout.readline, ''):
        plpy.info(line);

    p.wait()
$BODY$
LANGUAGE plpython3u VOLATILE;
```

When this `SELECT` command is run by the gpadmin user, the `analyzedb` utility performs an analyze operation on the table `public.mytable` that is in the database `mytest`.

```
SELECT analyzedb('-d mytest -t public.mytable') ;
```

> **Note** To create a PL/Python function, the PL/Python procedural language must be registered as a language in the database. For example, this `CREATE LANGUAGE` command run as gpadmin registers PL/Python as an untrusted language:

```
CREATE LANGUAGE plpython3u;
```

See Also

ANALYZE

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7.7.2.2 clusterdb

Reclusters tables that were previously clustered with `CLUSTER`.

Synopsis

```
clusterdb [<connection-option> ...] [--verbose | -v] [--table | -t <table>] [[--dbname | -d] <dbname]

clusterdb [<connection-option> ...] [--verbose | -v] --all | -a

clusterdb -? | --help

clusterdb -V | --version
```

Description

To cluster a table means to physically reorder a table on disk according to an index. Clustering helps improving index seek performance for queries that use that index. Clustering is a one-time operation: when the table is subsequently updated, the changes are not clustered. That is, no attempt is made to store new or updated rows according to their index order.

The `clusterdb` utility will find any tables in a database that have previously been clustered with the `CLUSTER` SQL command, and clusters them again on the same index that was last used. Tables that have never been clustered are not affected.

`clusterdb` is a wrapper around the SQL command CLUSTER. There is no effective difference between clustering databases via this utility and via other methods for accessing the server.

Options

`clusterdb` accepts the following command-line arguments:

-a --all Cluster all databases.

[-d] dbname [--dbname=]dbname Specifies the name of the database to be clustered, when `-a/--all` is not used. If this is not specified, the database name is read from the environment variable `PGDATABASE`. If that is not set, the user name specified for the connection is used. The dbname can be a connection string. If so, connection string parameters will override any conflicting command line options.

-e --echo Echo the commands that `clusterdb` generates and sends to the server.

-q --quiet Do not display progress messages.

-t table --table=table Cluster the named table only. You can cluster multiple tables by specifying multiple `-t` switches.

-v --verbose Print detailed information during processing.

-V --version Print the `clusterdb` version, and exit.

-? --help Show help about `clusterdb` command line arguments, and exit.

Connection Options

`clusterdb` also accepts the following command-line arguments for connection parameters:

-h host --host=host Specifies the host name of the machine on which the WarehousePG coordinator database server is running. If not specified, reads from the environment variable `PGHOST` or defaults to `localhost`.

-p port --port=port Specifies the TCP port on which the WarehousePG coordinator database server is listening for connections. If not specified, reads from the environment variable `PGPORT` or defaults to 5432.

-U username --username=username The database role name to connect as. If not specified, reads from the environment variable `PGUSER` or defaults to the current system role name.

-w --no-password Never issue a password prompt. If the server requires password authentication and a password is not available by other means such as a `.pgpass` file, the connection attempt will fail. This option can be useful in batch jobs and scripts where no user is present to enter a password.

-W --password Force `clusterdb` to prompt for a password before connecting to a database. This option is never essential, since `clusterdb` will automatically prompt for a password if the server demands password authentication. However, `clusterdb` will waste a connection attempt finding out that the server wants a password. In some cases it is worth typing `-W` to avoid the extra connection attempt.

--maintenance-db=dbname Specifies the name of the database to connect to discover what other databases should be clustered. If not specified, the `postgres` database will be used, and if that does not exist, `template1` will be used. This can be a connection string. If so, connection string parameters will override any conflicting command line options. Also, connection string parameters other than the database name itself will be re-used when connecting to other databases.

Environment

PGDATABASE PGHOST PGPORT PGUSER Default connection parameters.

PG_COLOR Specifies whether to use color in diagnostic messages. Possible values are `always`, `auto`, and `never`.

This utility, like most other WarehousePG utilities, also uses the environment variables supported by `libpq`.

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Diagnostics

In case of difficulty, see CLUSTER and psql for discussions of potential problems and error messages. The database server must be running at the targeted host. Also, any default connection settings and environment variables used by the `libpq` front-end library will apply.

Examples

To cluster the database named `test`:

```
clusterdb test
```

To cluster a single table `foo` in a database named `xyzzy`:

```
clusterdb --table=foo xyzzy
```

See Also

CLUSTER

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7.7.2.3 createdb

Creates a new database.

Synopsis

```
createdb [<connection-option> ...] [<option> ...] [<dbname> ['<description>']]

createdb -? | --help

createdb -V | --version
```

Description

`createdb` creates a new database in a WarehousePG cluster.

Normally, the database user who runs this command becomes the owner of the new database. However, a different owner can be specified via the `-O` option, if the executing user has appropriate privileges.

`createdb` is a wrapper around the SQL command CREATE DATABASE .

Options

dbname The name of the database to be created. The name must be unique among all other databases in the WarehousePG cluster. If not specified, reads from the environment variable `PGDATABASE`, then `PGUSER` or defaults to the current system user.

description A comment to be associated with the newly created database. Descriptions containing white space must be enclosed in quotes.

-D tablespace | --tablespace=tablespace Specifies the default tablespace for the database. (This name is processed as a double-quoted identifier.)

-e echo Echo the commands that `createdb` generates and sends to the server.

-E encoding | --encoding encoding Character set encoding to use in the new database. Specify a string constant (such as `'UTF8'`), an integer encoding number, or `DEFAULT` to use the default encoding. See the WarehousePG Reference Guide for information about supported character sets.

-l locale | --locale locale Specifies the locale to be used in this database. This is equivalent to specifying both `--lc-collate` and `--lc-ctype`.

--lc-collate locale Specifies the `LC_COLLATE` setting to be used in this database.

--lc-ctype locale Specifies the `LC_CTYPE` setting to be used in this database.

-O owner | --owner=owner The name of the database user who will own the new database. Defaults to the user running this command. (This name is processed as a double-quoted identifier.)

-T template | --template=template The name of the template from which to create the new database. Defaults to `template1`. (This name is processed as a double-quoted identifier.)

-V | --version Print the `createdb` version and exit.

-? | --help Show help about `createdb` command line arguments, and exit.

The options `-D`, `-l`, `-E`, `-O`, and `-T` correspond to options of the underlying SQL command `CREATE DATABASE`; see CREATE DATABASE in the *WarehousePG Reference Guide* for more information about them.

Connection Options

-h host | --host=host The host name of the machine on which the WarehousePG coordinator database server is running. If not specified, reads from the environment variable `PGHOST` or defaults to localhost.

-p port | --port=port The TCP port on which the WarehousePG coordinator database server is listening for connections. If not specified, reads from the environment variable `PGPORT` or defaults to 5432.

-U username | --username=username The database role name to connect as. If not specified, reads from the environment variable `PGUSER` or defaults to the current system role name.

-w | --no-password Never issue a password prompt. If the server requires password authentication and a password is not available by other means such as a `.pgpass` file, the connection attempt will fail. This option can be useful in batch jobs and scripts where no user is present to enter a password.

-W | --password Force a password prompt.

--maintenance-db=dbname Specifies the name of the database to connect to when creating the new database. If not specified, the `postgres` database will be used; if that does not exist (or if it is the name of the new database being created), `template1` will be used.

Examples

To create the database `test` using the default options:

```
createdb test
```

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To create the database `demo` using the WarehousePG coordinator on host `gpcoord`, port `54321`, using the `LATIN1` encoding scheme:

```
createdb -p 54321 -h gpcoord -E LATIN1 demo
```

See Also

CREATE DATABASE, dropdb

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7.7.2.4 createuser

Creates a new database role.

Synopsis

```
createuser [<connection-option> ...] [<role_attribute> ...] [-e] <role_name>

createuser -? | --help

createuser -V | --version
```

Description

`createuser` creates a new WarehousePG role. You must be a superuser or have the `CREATEROLE` privilege to create new roles. You must connect to the database as a superuser to create new superusers.

Superusers can bypass all access permission checks within the database, so superuser privileges should not be granted lightly.

`createuser` is a wrapper around the SQL command `CREATE ROLE`.

Options

role_name The name of the role to be created. This name must be different from all existing roles in this WarehousePG installation.

-c number | --connection-limit=number Set a maximum number of connections for the new role. The default is to set no limit.

-d | --createdb The new role will be allowed to create databases.

-D | --no-createdb The new role will not be allowed to create databases. This is the default.

-e | --echo Echo the commands that `createuser` generates and sends to the server.

-E | --encrypted Encrypts the role's password stored in the database. If not specified, the default password behavior is used.

-i | --inherit The new role will automatically inherit privileges of roles it is a member of. This is the default.

-I | --no-inherit The new role will not automatically inherit privileges of roles it is a member of.

--interactive Prompt for the user name if none is specified on the command line, and also prompt for whichever of the options `-d` / `-D`, `-r` / `-R`, `-s` / `-S` is not specified on the command line.

-l | --login The new role will be allowed to log in to WarehousePG. This is the default.

-L | --no-login The new role will not be allowed to log in (a group-level role).

-N | --unencrypted Does not encrypt the role's password stored in the database. If not specified, the default password behavior is used.

-P | --pwprompt If given, `createuser` will issue a prompt for the password of the new role. This is not necessary if you do not plan on using password authentication.

-r | --createrole The new role will be allowed to create new roles (`CREATEROLE` privilege).

-R | --no-createrole The new role will not be allowed to create new roles. This is the default.

-s | --superuser The new role will be a superuser.

-S | --no-superuser The new role will not be a superuser. This is the default.

-V | --version Print the `createuser` version and exit.

--replication The new user will have the `REPLICATION` privilege, which is described more fully in the documentation for CREATE ROLE.

--no-replication The new user will not have the `REPLICATION` privilege, which is described more fully in the documentation for CREATE ROLE.

-? | --help Show help about `createuser` command line arguments, and exit.

Connection Options

-h host | --host=host The host name of the machine on which the WarehousePG coordinator database server is running. If not specified, reads from the environment variable `PGHOST` or defaults to localhost.

-p port | --port=port The TCP port on which the WarehousePG coordinator database server is listening for connections. If not specified, reads from the environment variable `PGPORT` or defaults to 5432.

-U username | --username=username The database role name to connect as. If not specified, reads from the environment variable `PGUSER` or defaults to the current system role name.

-w | --no-password Never issue a password prompt. If the server requires password authentication and a password is not available by other means such as a `.pgpass` file, the connection attempt will fail. This option can be useful in batch jobs and scripts where no user is present to enter a password.

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-W | --password Force a password prompt.

Examples

To create a role `joe` on the default database server:

```
$ createuser joe
```

To create a role `joe` on the default database server with prompting for some additional attributes:

```
$ createuser --interactive joe
Shall the new role be a superuser? (y/n) **n**
Shall the new role be allowed to create databases? (y/n) **n**
Shall the new role be allowed to create more new roles? (y/n) **n**
CREATE ROLE
```

To create the same role `joe` using connection options, with attributes explicitly specified, and taking a look at the underlying command:

```
createuser -h coordinatorhost -p 54321 -S -D -R -e joe
CREATE ROLE joe NOSUPERUSER NOCREATEDB NOCREATEROLE INHERIT
LOGIN;
CREATE ROLE
```

To create the role `joe` as a superuser, and assign password `admin123` immediately:

```
createuser -P -s -e joe
Enter password for new role: admin123
Enter it again: admin123
CREATE ROLE joe PASSWORD 'admin123' SUPERUSER CREATEDB
CREATEROLE INHERIT LOGIN;
CREATE ROLE
```

In the above example, the new password is not actually echoed when typed, but we show what was typed for clarity. However the password will appear in the echoed command, as illustrated if the `-e` option is used.

See Also

CREATE ROLE, dropuser

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7.7.2.5 dropdb

Removes a database.

Synopsis

```
dropdb [<connection-option> ...] [-e] [-i] <dbname>

dropdb -? | --help

dropdb -V | --version
```

Description

`dropdb` destroys an existing database. The user who runs this command must be a superuser or the owner of the database being dropped.

`dropdb` is a wrapper around the SQL command `DROP DATABASE`. See the *WarehousePG Reference Guide* for information about `DROP DATABASE`.

Options

dbname The name of the database to be removed.

-e | --echo Echo the commands that `dropdb` generates and sends to the server.

-i | --interactive Issues a verification prompt before doing anything destructive.

-V | --version Print the `dropdb` version and exit.

--if-exists Do not throw an error if the database does not exist. A notice is issued in this case.

-? | --help Show help about `dropdb` command line arguments, and exit.

Connection Options

-h host | --host=host The host name of the machine on which the WarehousePG coordinator database server is running. If not specified, reads from the environment variable `PGHOST` or defaults to localhost.

-p port | --port=port The TCP port on which the WarehousePG coordinator database server is listening for connections. If not specified, reads from the environment variable `PGPORT` or defaults to 5432.

-U username | --username=username The database role name to connect as. If not specified, reads from the environment variable `PGUSER` or defaults to the current system role name.

-w | --no-password Never issue a password prompt. If the server requires password authentication and a password is not available by other means such as a `.pgpass` file, the connection attempt will fail. This option can be useful in batch jobs and scripts where no user is present to enter a password.

-W | --password Force a password prompt.

--maintenance-db=dbname Specifies the name of the database to connect to in order to drop the target database. If not specified, the `postgres` database will be used; if that does not exist (or if it is the name of the database being dropped), `template1` will be used.

Examples

To destroy the database named `demo` using default connection parameters:

```
dropdb demo
```

To destroy the database named `demo` using connection options, with verification, and a peek at the underlying command:

```
dropdb -p 54321 -h coordinatorhost -i -e demo
Database "demo" will be permanently deleted.
Are you sure? (y/n) y
DROP DATABASE "demo"
DROP DATABASE
```

See Also

createdb, DROP DATABASE

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7.7.2.6 dropuser

Removes a database role.

Synopsis

```
dropuser [<connection-option> ...] [-e] [-i] <role_name>

dropuser -? | --help

dropuser -V | --version
```

Description

`dropuser` removes an existing role from WarehousePG. Only superusers and users with the `CREATEROLE` privilege can remove roles. To remove a superuser role, you must yourself be a superuser.

`dropuser` is a wrapper around the SQL command `DROP ROLE`.

Options

role_name The name of the role to be removed. You will be prompted for a name if not specified on the command line and the `-i` / `--interactive` option is used.

-e | --echo Echo the commands that `dropuser` generates and sends to the server.

-i | --interactive Prompt for confirmation before actually removing the role, and prompt for the role name if none is specified on the command line.

--if-exists Do not throw an error if the user does not exist. A notice is issued in this case.

-V | --version Print the `dropuser` version and exit.

-? | --help Show help about `dropuser` command line arguments, and exit.

Connection Options

-h host | --host=host The host name of the machine on which the WarehousePG coordinator database server is running. If not specified, reads from the environment variable `PGHOST` or defaults to localhost.

-p port | --port=port The TCP port on which the WarehousePG coordinator database server is listening for connections. If not specified, reads from the environment variable `PGPORT` or defaults to 5432.

-U username | --username=username The database role name to connect as. If not specified, reads from the environment variable `PGUSER` or defaults to the current system role name.

-w | --no-password Never issue a password prompt. If the server requires password authentication and a password is not available by other means such as a `.pgpass` file, the connection attempt will fail. This option can be useful in batch jobs and scripts where no user is present to enter a password.

-W | --password Force a password prompt.

Examples

To remove the role `joe` using default connection options:

```
dropuser joe
DROP ROLE
```

To remove the role joe using connection options, with verification, and a peek at the underlying command:

```
dropuser -p 54321 -h coordinatorhost -i -e joe
Role "joe" will be permanently removed.
Are you sure? (y/n) y
DROP ROLE "joe"
DROP ROLE
```

See Also

createuser, DROP ROLE

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7.7.2.7 gpactivatestandby

Activates a standby coordinator host and makes it the active coordinator for the WarehousePG cluster.

Synopsis

```
gpactivatestandby [-d <standby_coordinator_datadir>] [-f] [-a] [-q]
    [-l <logfile_directory>]

gpactivatestandby -v

gpactivatestandby -? | -h | --help
```

Description

The `gpactivatestandby` utility activates a backup, standby coordinator host and brings it into operation as the active coordinator instance for a WarehousePG cluster. The activated standby coordinator effectively becomes the WarehousePG coordinator, accepting client connections on the coordinator port.

> **NOTE** Before running `gpactivatestandby`, be sure to run `gpstate -f` to confirm that the standby coordinator is synchronized with the current coordinator node. If synchronized, the final line of the `gpstate -f` output will look similar to this: `20230607:06:50:06:004205 gpstate:test1-m:gpadmin-[INFO]:--Sync state: sync`

When you initialize a standby coordinator, the default is to use the same port as the active coordinator. For information about the coordinator port for the standby coordinator, see gpinitstandby.

You must run this utility from the coordinator host you are activating, not the failed coordinator host you are deactivating. Running this utility assumes you have a standby coordinator host configured for the system (see gpinitstandby).

The utility will perform the following steps:

- Stops the synchronization process (`walreceiver`) on the standby coordinator
- Updates the system catalog tables of the standby coordinator using the logs
- Activates the standby coordinator to be the new active coordinator for the system
- Restarts the WarehousePG cluster with the new coordinator host

A backup, standby WarehousePG coordinator host serves as a 'warm standby' in the event of the primary WarehousePG coordinator host becoming non-operational. The standby coordinator is kept up to date by transaction log replication processes (the `walsender` and `walreceiver`), which run on the primary coordinator and standby coordinator hosts and keep the data between the primary and standby coordinator hosts synchronized.

If the primary coordinator fails, the log replication process is shutdown, and the standby coordinator can be activated in its place by using the `gpactivatestandby` utility. Upon activation of the standby coordinator, the replicated logs are used to reconstruct the state of the WarehousePG coordinator host at the time of the last successfully committed transaction.

In order to use `gpactivatestandby` to activate a new primary coordinator host, the coordinator host that was previously serving as the primary coordinator cannot be running. The utility checks for a `postmaster.pid` file in the data directory of the deactivated coordinator host, and if it finds it there, it will assume the old coordinator host is still active. In some cases, you may need to remove the `postmaster.pid` file from the deactivated coordinator host data directory before running `gpactivatestandby` (for example, if the deactivated coordinator host process was terminated unexpectedly).

After activating a standby coordinator, run `ANALYZE` to update the database query statistics. For example:

```
psql <dbname> -c 'ANALYZE;'
```

After you activate the standby coordinator as the primary coordinator, the WarehousePG cluster no longer has a standby coordinator configured. You might want to specify another host to be the new standby with the gpinitstandby utility.

Options

-a (do not prompt) Do not prompt the user for confirmation.

-d standby_coordinator_datadir The absolute path of the data directory for the coordinator host you are activating.

If this option is not specified, `gpactivatestandby` uses the value of the `COORDINATOR_DATA_DIRECTORY` environment variable setting on the coordinator host you are activating. If this option is specified, it overrides any setting of `COORDINATOR_DATA_DIRECTORY`.

If a directory cannot be determined, the utility returns an error.

-f (force activation) Use this option to force activation of the backup coordinator host. Use this option only if you are sure that the standby and primary coordinator hosts are consistent.

-l logfile_directory The directory to write the log file. Defaults to `~/gpAdminLogs`.

-q (no screen output) Run in quiet mode. Command output is not displayed on the screen, but is still written to the log file.

-v (show utility version) Displays the version, status, last updated date, and check sum of this utility.

-? | -h | --help (help) Displays the online help.

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Example

Activate the standby coordinator host and make it the active coordinator instance for a WarehousePG cluster (run from backup coordinator host you are activating):

```
gpactivatestandby -d /gpdata
```

See Also

gpinitsystem, gpinitstandby

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7.7.2.8 gpaddmirrors

Adds mirror segments to a WarehousePG cluster that was initially configured without mirroring.

Synopsis

```
gpaddmirrors [-p <port_offset>] [-m <datadir_config_file> [-a]] [-s]
   [-d <coordinator_data_directory>] [-b <segment_batch_size>] [-B <batch_size>] [-l <logfile_directory>]
   [-v] [--hba-hostnames <boolean>]

gpaddmirrors -i <mirror_config_file> [-a] [-d <coordinator_data_directory>]
   [-b <segment_batch_size>] [-B <batch_size>] [-l <logfile_directory>] [-v]

gpaddmirrors -o output_sample_mirror_config> [-s] [-m <datadir_config_file>]

gpaddmirrors -?

gpaddmirrors --version
```

Description

The `gpaddmirrors` utility configures mirror segment instances for an existing WarehousePG cluster that was initially configured with primary segment instances only. The utility will create the mirror instances and begin the online replication process between the primary and mirror segment instances. Once all mirrors are synchronized with their primaries, your WarehousePG cluster is fully data redundant.

> **Important**
>
> During the online replication process, WarehousePG should be in a quiescent state, workloads and other queries should not be running.

By default, the utility will prompt you for the file system location(s) where it will create the mirror segment data directories. If you do not want to be prompted, you can pass in a file containing the file system locations using the `-m` option.

The mirror locations and ports must be different than your primary segment data locations and ports.

The utility creates a unique data directory for each mirror segment instance in the specified location using the predefined naming convention. There must be the same number of file system locations declared for mirror segment instances as for primary segment instances. It is OK to specify the same directory name multiple times if you want your mirror data directories created in the same location, or you can enter a different data location for each mirror. Enter the absolute path. For example:

```
Enter mirror segment data directory location 1 of 2 > /gpdb/mirror
Enter mirror segment data directory location 2 of 2 > /gpdb/mirror
```

OR

```
Enter mirror segment data directory location 1 of 2 > /gpdb/m1
Enter mirror segment data directory location 2 of 2 > /gpdb/m2
```

Alternatively, you can run the `gpaddmirrors` utility and supply a detailed configuration file using the `-i` option. This is useful if you want your mirror segments on a completely different set of hosts than your primary segments. The format of the mirror configuration file is:

```
<contentID>|<address>|<port>|<data_dir>
```

Where `<contentID>` is the segment instance content ID, `<address>` is the host name or IP address of the segment host, `<port>` is the communication port, and `<data_dir>` is the segment instance data directory.

For example:

```
0|sdw1-1|60000|/gpdata/m1/gp0
1|sdw1-1|60001|/gpdata/m2/gp1
```

The `gp_segment_configuration` system catalog table can help you determine your current primary segment configuration so that you can plan your mirror segment configuration. For example, run the following query:

```
=# SELECT dbid, content, address as host_address, port, datadir
   FROM gp_segment_configuration
   ORDER BY dbid;
```

If you are creating mirrors on alternate mirror hosts, the new mirror segment hosts must be pre-installed with the WarehousePG software and configured exactly the same as the existing primary segment hosts.

You must make sure that the user who runs `gpaddmirrors` (the `gpadmin` user) has permissions to write to the data directory locations specified. You may want to create these directories on the segment hosts and `chown` them to the appropriate user before running `gpaddmirrors`.

> **Note**
>
> This utility uses secure shell (SSH) connections between systems to perform its tasks. In large WarehousePG deployments, cloud deployments, or deployments with a large number of segments per host, this utility may exceed the host's maximum threshold for unauthenticated connections. Consider updating the SSH `MaxStartups` configuration parameter to increase this threshold. For more information about SSH configuration options, refer to the SSH documentation for your Linux distribution.

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Options

-a (do not prompt)

Run in quiet mode - do not prompt for information. Must supply a configuration file with either `-m` or `-i` if this option is used.

-b segment_batch_size

The maximum number of segments per host to operate on in parallel. Valid values are `1` to `128`. If not specified, the utility will start recovering up to 64 segments in parallel on each host.

-B batch_size

The number of hosts to work on in parallel. If not specified, the utility will start working on up to 16 hosts in parallel. Valid values are `1` to `64`.

-d coordinator_data_directory

The coordinator data directory. If not specified, the value set for `$COORDINATOR_DATA_DIRECTORY` will be used.

--hba-hostnames boolean

Optional. Controls whether this utility uses IP addresses or host names in the `pg_hba.conf` file when updating this file with addresses that can connect to WarehousePG. When set to 0 -- the default value -- this utility uses IP addresses when updating this file. When set to 1, this utility uses host names when updating this file. For consistency, use the same value that was specified for `HBA_HOSTNAMES` when the WarehousePG cluster was initialized. For information about how WarehousePG resolves host names in the `pg_hba.conf` file, see Configuring Client Authentication.

-i mirror_config_file

A configuration file containing one line for each mirror segment you want to create. You must have one mirror segment instance listed for each primary segment in the system. The format of this file is as follows (as per attributes in the gp_segment_configuration catalog table):

```
<contentID>|<address>|<port>|<data_dir>
```

Where `<contentID>` is the segment instance content ID, `<address>` is the hostname or IP address of the segment host, `<port>` is the communication port, and `<data_dir>` is the segment instance data directory. For information about using a hostname or IP address, see Specifying Hosts using Hostnames or IP Addresses. Also, see Using Host Systems with Multiple NICs.

-l logfile_directory

The directory to write the log file. Defaults to `~/gpAdminLogs`.

-m datadir_config_file

A configuration file containing a list of file system locations where the mirror data directories will be created. If not supplied, the utility prompts you for locations. Each line in the file specifies a mirror data directory location. For example:

```
/gpdata/m1
/gpdata/m2
/gpdata/m3
/gpdata/m4
```

-o output_sample_mirror_config

If you are not sure how to lay out the mirror configuration file used by the `-i` option, you can run `gpaddmirrors` with this option to generate a sample mirror configuration file based on your primary segment configuration. The utility will prompt you for your mirror segment data directory locations (unless you provide these in a file using `-m`). You can then edit this file to change the host names to alternate mirror hosts if necessary.

-p port_offset

Optional. This number is used to calculate the database ports used for mirror segments. The default offset is 1000. Mirror port assignments are calculated as follows:

```
```
primary_port + offset = mirror_database_port
```
```

For example, if a primary segment has port 50001, then its mirror will use a database port of 51001, by default.

-s (spread mirrors)

Spreads the mirror segments across the available hosts. The default is to group a set of mirror segments together on an alternate host from their primary segment set. Mirror spreading will place each mirror on a different host within the WarehousePG cluster. Spreading is only allowed if there is a sufficient number of hosts in the array (number of hosts is greater than the number of segment instances per host).

-v (verbose)

Sets logging output to verbose.

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--version (show utility version)

Displays the version of this utility.

-? (help)

Displays the online help.

Specifying Hosts using Hostnames or IP Addresses

When specifying a mirroring configuration using the `gpaddmirrors` option `-i`, you can specify either a hostname or an IP address for the <address> value.

- If you specify a hostname, the resolution of the hostname to an IP address should be done locally for security. For example, you should use entries in a local `/etc/hosts` file to map the hostname to an IP address. The resolution of a hostname to an IP address should not be performed by an external service such as a public DNS server. You must stop the WarehousePG cluster before you change the mapping of a hostname to a different IP address.
- If you specify an IP address, the address should not be changed after the initial configuration. When segment mirroring is enabled, replication from the primary to the mirror segment will fail if the IP address changes from the configured value. For this reason, you should use a hostname when enabling mirroring using the `-i` option unless you have a specific requirement to use IP addresses.

When enabling a mirroring configuration that adds hosts to the WarehousePG cluster, `gpaddmirrors` populates the gp_segment_configuration catalog table with the mirror segment instance information. WarehousePG uses the address value of the `gp_segment_configuration` catalog table when looking up host systems for WarehousePG interconnect (internal) communication between the coordinator and segment instances and between segment instances, and for other internal communication.

Using Host Systems with Multiple NICs

If hosts systems are configured with multiple NICs, you can initialize a WarehousePG cluster to use each NIC as a WarehousePG host system. You must ensure that the host systems are configured with sufficient resources to support all the segment instances being added to the host. Also, if you enable segment mirroring, you must ensure that the WarehousePG cluster configuration supports failover if a host system fails. For information about WarehousePG mirroring schemes, see Segment Mirroring Configurations.

For example, this is a segment instance configuration for a simple WarehousePG cluster. The segment host `gp7c` is configured with two NICs, `gp7c-1` and `gp7c-2`, where the WarehousePG cluster uses `gp7c-1` for the coordinator segment and `gp7c-2` for segment instances.

```
select content, role, port, hostname, address from gp_segment_configuration ;

 content | role | port  | hostname | address
---------+------+-------+----------+----------
      -1 | p    |  5432 | gp7c     | gp7c-1
       0 | p    | 40000 | gp7c     | gp7c-2
       0 | m    | 50000 | gp7s     | gp7s
       1 | p    | 40000 | gp7s     | gp7s
       1 | m    | 50000 | gp7c     | gp7c-2
(5 rows)
```

Examples

Add mirroring to an existing WarehousePG cluster using the same set of hosts as your primary data. Calculate the mirror database ports by adding 100 to the current primary segment port numbers:

```
$ gpaddmirrors -p 100
```

Generate a sample mirror configuration file with the `-o` option to use with `gpaddmirrors -i`:

```
$ gpaddmirrors -o /home/gpadmin/sample_mirror_config
```

Add mirroring to an existing WarehousePG cluster using a different set of hosts from your primary data:

```
$ gpaddmirrors -i mirror_config_file
```

Where `mirror_config_file` looks something like this:

```
0|sdw1-1|52001|/gpdata/m1/gp0
1|sdw1-2|52002|/gpdata/m2/gp1
2|sdw2-1|52001|/gpdata/m1/gp2
3|sdw2-2|52002|/gpdata/m2/gp3
```

See Also

gpinitsystem, gpinitstandby, gpactivatestandby

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7.7.2.9 gpbackup

Create backup metadata and data files of a WarehousePG cluster compatible with the `gprestore` utility

Synopsis

```
gpbackup --dbname <database_name>
   [--backup-dir <directory>]
   [--compression-level <level>]
   [--compression-type <type>]
   [--copy-queue-size <int>]
   [--data-only]
   [--debug]
   [--exclude-schema <schema_name> [--exclude-schema <schema_name> ...]]
   [--exclude-table <schema.table> [--exclude-table <schema.table> ...]]
   [--exclude-schema-file <file_name>]
   [--exclude-table-file <file_name>]
   [--include-schema <schema_name> [--include-schema <schema_name> ...]]
   [--include-table <schema.table> [--include-table <schema.table> ...]]
   [--include-schema-file <file_name>]
   [--include-table-file <file_name>]
   [--incremental [--from-timestamp <backup-timestamp>]]
   [--jobs <int>]
   [--leaf-partition-data]
   [--metadata-only]
   [--no-compression]
   [--no-inherits]
   [--no-history]
   [--plugin-config <config_file_location>]
   [--quiet]
   [--single-data-file]
   [--single-backup-dir]
   [--verbose]
   [--version]
   [--with-stats]
   [--without-globals]

gpbackup --help
```

`gprestore` reference

Description

The `gpbackup` utility backs up the contents of a database into a collection of metadata files and data files that can be used to restore the database at a later time using gprestore. When you back up a database, you can specify table level and schema level filter options to back up specific tables. For example, you can combine schema level and table level options to back up all the tables in a schema except for a single table.

By default, `gpbackup` backs up objects in the specified database as well as global WarehousePG system objects. Use `--without-globals` to omit global objects. gprestore does not restore global objects by default; use `--with-globals` to restore them.

See Objects Included in a Backup or Restore for additional information.

For materialized views, data is not backed up, only the materialized view definition is backed up.

gpbackup stores the object metadata files and DDL files for a backup in the WarehousePG coordinator data directory by default. WarehousePG segments use the `COPY ... ON SEGMENT` command to store their data for backed-up tables in compressed CSV data files, located in each segment's data directory. See Understanding Backup Files for additional information.

You can add the `--backup-dir` option to copy all backup files from the WarehousePG coordinator and segment hosts to an absolute path for later use. Additional options are provided to filter the backup set in order to include or exclude specific tables.

You can create an incremental backup with the `--incremental` option. Incremental backups are efficient when the total amount of data in append-optimized tables or table partitions that changed is small compared to the data has not changed. See Creating and Using Incremental Backups with `gpbackup` and gprestore for information about incremental backups.

With the default `--jobs` option (1 job), each `gpbackup` operation uses a single transaction on the WarehousePG coordinator host. The `COPY ... ON SEGMENT` command performs the backup task in parallel on each segment host. The backup process acquires an `ACCESS SHARE` lock on each table that is backed up. During the table locking process, the database should be in a quiescent state.

When a back up operation completes, `gpbackup` returns a status code. See Return Codes.

The `gpbackup` utility cannot be run while gpexpand is initializing new segments. Backups created before the expansion cannot be restored with gprestore after the cluster expansion is completed.

`gpbackup` can send status email notifications after a back up operation completes. You specify when the utility sends the mail and the email recipients in a configuration file. See Configuring Email Notifications.

> **Note**
>
> This utility uses secure shell (SSH) connections between systems to perform its tasks. In large WarehousePG deployments, cloud deployments, or deployments with a large number of segments per host, this utility may exceed the host's maximum threshold for unauthenticated connections. Consider updating the `SSH MaxStartups` and `MaxSessions` configuration parameters to increase this threshold. For more information about SSH configuration options, refer to the SSH documentation for your Linux distribution.

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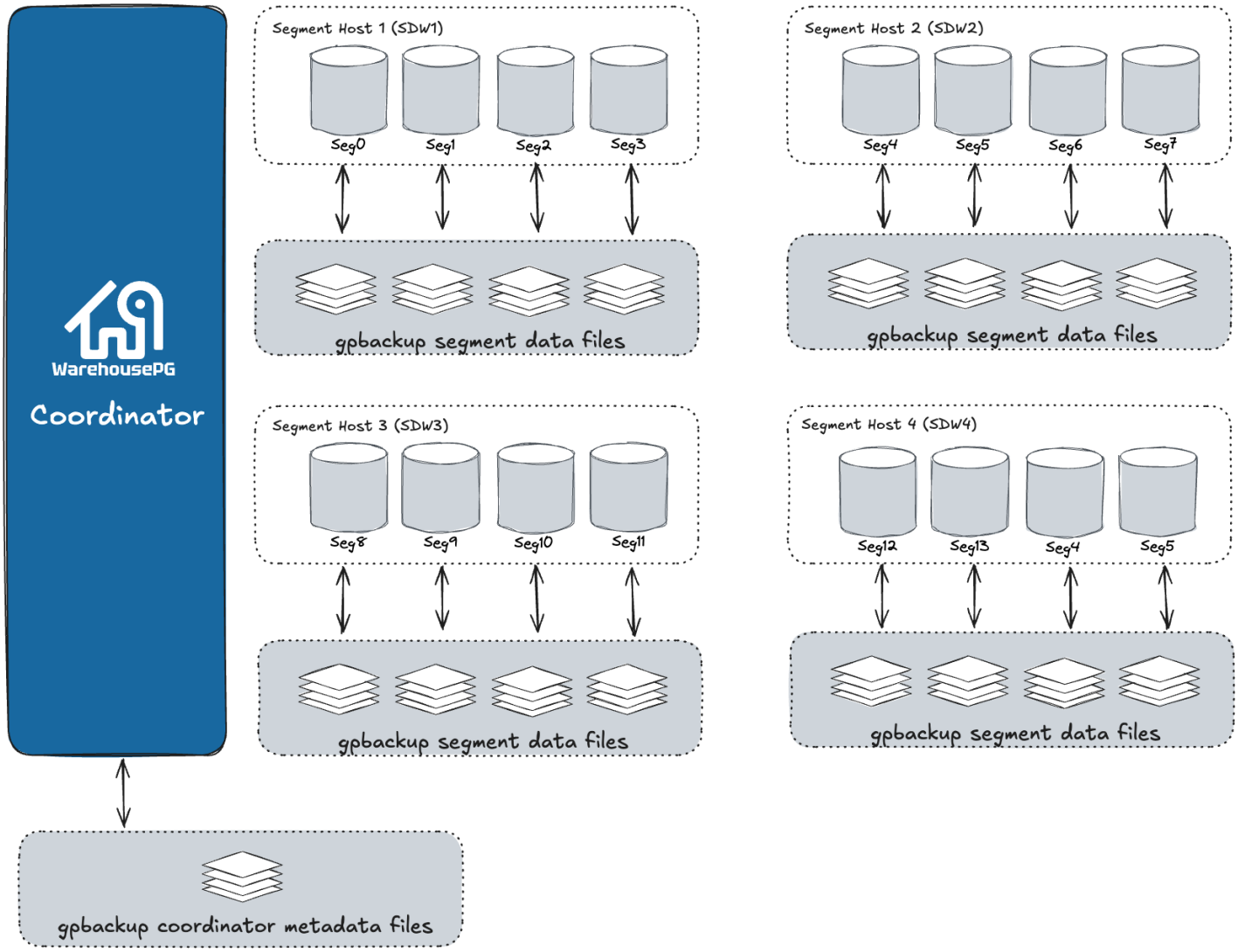
Parallel Backup with gpbackup and gprestore



Options

`--dbname database_name`
Required. Specifies the database to back up.

`--backup-dir <directory>`
Optional. Copies all required backup files (metadata files and data files) to the specified directory. You must specify directory as an absolute path (not relative). If you do not supply this option, metadata files are created on the WarehousePG coordinator host in the `$MASTER_DATA_DIRECTORY/backups/YYYYMMDD/YYYYMMDDhhmmss/` directory. Segment hosts create CSV data files in the `<seg_dir>/backups/YYYYMMDD/YYYYMMDDhhmmss/` directory. When you specify a custom backup directory, files are copied to these paths in subdirectories of the backup directory.

When invoked together with the `--metadata-only` and `--no-history` options, a backup may have the same timestamp as another backup, provided that each of the two backups has a distinct `--backup-dir` location.

You cannot combine this option with the option `--plugin-config`.

`--compression-level <level>`
Optional. Specifies the compression level (from 1 to 9) used to compress data files. The default is 1.

> **Note**
>
> `gpbackup` uses compression by default.

`--compression-type <type>`
Optional. Specifies the compression type (gzip or zstd) used to compress data files. The default is gzip.

> **Note**
>
> In order to use the zstd compression type, Zstandard must be installed in a `$PATH` accessible by the `gpadmin` user.

`--copy-queue-size int`
Optional. Specifies the number of `COPY` commands `gpbackup` should enqueue when backing up using the `--single-data-file` option. This option optimizes backup performance by reducing the amount of time spent initializing `COP`Y commands. If you do not set this option to 2 or greater, `gpbackup` enqueues 1 `COPY` command at a time.

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> **Note**
>
> This option must be used with the `--single-data-file` option and cannot be used with the `--jobs` option.

`--data-only`
Optional. Backs up only the table data into CSV files, but does not backup metadata files needed to recreate the tables and other database objects.

`--debug`
Optional. Displays verbose debug messages during operation.

`--exclude-schema <schema_name>`
Optional. Specifies a database schema to exclude from the backup. You can specify this option multiple times to exclude multiple schemas. You cannot combine this option with the option `--include-schema`, `--include-schema-file`, or a table filtering option such as `--include-table`.

See Filtering the Contents of a Backup or Restore for more information.

See Requirements and Limitations for limitations when leaf partitions of a partitioned table are in different schemas from the root partition.

`--exclude-schema-file <file_name>`
Optional. Specifies a text file containing a list of schemas to exclude from the backup. Each line in the text file must define a single schema. The file must not include trailing lines. If a schema name uses any character other than a lowercase letter, number, or an underscore character, then you must include that name in double quotes. You cannot combine this option with the option `--include-schema` or `--include-schema-file`, or a table filtering option such as `--include-table`.

See Filtering the Contents of a Backup or Restore for more information.

See Requirements and Limitations for limitations when leaf partitions of a partitioned table are in different schemas from the root partition.

`--exclude-table <schema.table>`
Optional. Specifies a table to exclude from the backup. The table must be in the format `<schema-name>.<table-name>`. If a table or schema name uses any character other than a lowercase letter, number, or an underscore character, then you must include that name in double quotes. You can specify this option multiple times. You cannot combine this option with the option `--exclude-schema`, `--exclude-schema-file`, or another a table filtering option such as `--include-table`.

If you specify a leaf partition name, `gpbackup` ignores the partition names. The leaf partition is not excluded.

See Filtering the Contents of a Backup or Restore for more information.

`--exclude-table-file <file_name>`
Optional. Specifies a text file containing a list of tables to exclude from the backup. Each line in the text file must define a single table using the format `<schema-name>.<table-name>`. The file must not include trailing lines. If a table or schema name uses any character other than a lowercase letter, number, or an underscore character, then you must include that name in double quotes. You cannot combine this option with the option `--exclude-schema`, `--exclude-schema-file`, or another a table filtering option such as `--include-table`.

If you specify leaf partition names in a file that is used with --exclude-table-file, `gpbackup` ignores the partition names. The leaf partitions are not excluded.

See Filtering the Contents of a Backup or Restore for more information.

`--include-schema <schema_name>`
Optional. Specifies a database schema to include in the backup. You can specify this option multiple times to include multiple schemas. If you specify this option, any schemas that are not included in subsequent `--include-schema` options are omitted from the backup set. You cannot combine this option with the options `--exclude-schema`, `--exclude-schema-file`, `--exclude-schema-file`, `--include-table`, or `--include-table-file`. See Filtering the Contents of a Backup or Restore for more information.

`--include-schema-file <file_name>`
Optional. Specifies a text file containing a list of schemas to back up. Each line in the text file must define a single schema. The file must not include trailing lines. If a schema name uses any character other than a lowercase letter, number, or an underscore character, then you must include that name in double quotes.

See Filtering the Contents of a Backup or Restore for more information.

`--include-table <schema.table>`
Optional. Specifies a table to include in the backup. The table must be in the format `<schema-name>.<table-name>`.

You can specify this option multiple times. You cannot combine this option with a schema filtering option such as `--include-schema`, or another table filtering option such as `--exclude-table-file`.

You can also specify the qualified name of a sequence, a view, or a materialized view.

If you specify this option, the utility does not automatically back up dependent objects. You must also explicitly specify dependent objects that are Required. For example if you back up a view or a materialized view, you must also back up the tables that the view or materialized view uses. If you back up a table that uses a sequence, you must also back up the sequence.

You can optionally specify a table leaf partition name in place of the table name, to include only specific leaf partitions in a backup with the `--leaf-partition-dat` a option. When a leaf partition is backed up, the leaf partition data is backed up along with the metadata for the partitioned table.

See Filtering the Contents of a Backup or Restore for more information.

`--include-table-file <file_name>`
Optional. Specifies a text file containing a list of tables to include in the backup. Each line in the text file must define a single table using the format `<schema-name>.<table-name>`. The file must not include trailing lines. For information on specifying special characters in schema and table names, see Schema and Table Names.

Any tables not listed in this file are omitted from the backup set. You cannot combine this option with a schema filtering option such as `--include-schem` a, or another table filtering option such as `--exclude-table-file`.

You can also specify the qualified name of a sequence, a view, or a materialized view.

If you specify this option, the utility does not automatically back up dependent objects. You must also explicitly specify dependent objects that are Required. For example if you back up a view or a materialized view, you must also specify the tables that the view or the materialized view uses. If you specify a table that uses a sequence, you must also specify the sequence.

You can optionally specify a table leaf partition name in place of the table name, to include only specific leaf partitions in a backup with the `--leaf-partition-data` option. When a leaf partition is backed up, the leaf partition data is backed up along with the metadata for the partitioned table.

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See Filtering the Contents of a Backup or Restore for more information.

`--incremental`
Specify this option to add an incremental backup to an incremental backup set. A backup set is a full backup and one or more incremental backups. The backups in the set must be created with a consistent set of backup options to ensure that the backup set can be used in a restore operation.

By default, `gpbackup` attempts to find the most recent existing backup with a consistent set of options. If the backup is a full backup, the utility creates a backup set. If the backup is an incremental backup, the utility adds the backup to the existing backup set. The incremental backup is added as the latest backup in the backup set. You can specify `--from-timestamp` to override the default behavior.

> `--from-timestamp <backup-timestamp>`
> Optional. Specifies the timestamp of a backup. The specified backup must have backup options that are consistent with the incremental backup that is >being created. If the specified backup is a full backup, the utility creates a backup set. If the specified backup is an incremental backup, the >utility adds the incremental backup to the existing backup set.
>
> You must specify `--leaf-partition-dat` a with this option. You cannot combine this option with `--data-only` or `--metadata-only`.
>
> A backup is not created and the utility returns an error if the backup cannot add the backup to an existing incremental backup set or cannot use the >backup to create a backup set.

For information about creating and using incremental backups, see Creating and Using Incremental Backups with gpbackup and gprestore.

`--jobs <int>`
Optional. Specifies the number of jobs to run in parallel when backing up tables. By default, `gpbackup` uses 1 job (database connection). Increasing this number can improve the speed of backing up data. When running multiple jobs, each job backs up tables in separate transactions.

Important: If you specify a value higher than 1, the database should be in a quiescent state while the utility acquires a lock on the tables that are being backed up. If the utility cannot acquire a lock on a table being backed up it will exit.

You cannot use this option in combination with the options `--metadata-only`, `--single-data-file`, or `--plugin-config`.

> **Note**
>
> This option must be used with the `--single-data-file` option and cannot be used with the `--jobs` option. When using the `--jobs` flag, there is a potential deadlock scenario to generate a WARNING message in the log files. During the metadata portion of the backup, the main worker process gathers Access Share locks on all the tables in the backup set. During the data portion of the backup, based on the value of the `--jobs` flag, additional workers are created that attempt to take additional Access Share locks on the tables they back up.
>
> Between the metadata backup and the data backup, if a third party process (operations like `TRUNCATE`, `DROP`, `ALTER`) attempts to access the same tables and obtain an `Exclusive` lock, the worker thread identifies the potential deadlock and hands off the table backup responsibilities to the main worker (that already has an `Access Share` lock on that particular table). A warning message is logged, similar to: `[WARNING]:-Worker 5 could not acquire AccessShareLock for table public.foo.`

`--leaf-partition-data`
Optional. For partitioned tables, creates one data file per leaf partition instead of one data file for the entire table (the default). Using this option also enables you to specify individual leaf partitions to include in or exclude from a backup, with the `--include-table,` --include-table-file `,` --exclude-table `, and` --exclude-table-file` options.

`--metadata-only`
Optional. Creates only the metadata files (DDL) needed to recreate the database objects, but does not back up the actual table data.

`--no-compression`
Optional. Do not compress the table data CSV files.

`--no-history`
Optional. When invoked, `gpbackup` does not write backup run metadata to the history database. This is useful if you prefer not to have an application-maintained SQLite database on your system. However, if you choose not to back up to the history database you lose access to the features of the gpbackup_manager utility.

`--no-inherits`
Optional. Only works when invoked with either the `--include-table` option or the `--include-table-file` option. When invoked, only the metadata of the table itself is backed up, ignoring any inheritance relationships with other tables that would normally cause those tables to also be included in the backup set.

`--plugin-config <config-file_location>`
Specify the location of the `gpbackup` plugin configuration file, a YAML-formatted text file. The file contains configuration information for the plugin application that `gpbackup` uses during the backup operation.

If you specify the `--plugin-config` option when you back up a database, you must specify this option with configuration information for a corresponding plugin application when you restore the database from the backup.

You cannot combine this option with the option `--backup-dir`.

For information about using storage plugin applications, see Using gpbackup Storage Plugins.

`--quiet`
Optional. Suppress all non-warning, non-error log messages.

`--single-backup-dir`
Optional. Store all backup files on a given host in a single directory rather than in distinct per-segment subdirectories under the chosen backup directory. For example, files that were previously created in the `<backup-dir>/gpseg0/backups/<datestamp>/<timestamp>` or `<backup-dir>/gpseg1/backups/<datestamp>/<timestamp>` directories will now be created under `<backup-dir>/backups/<datestamp>/<timestamp>`. You may restore backups taken with this option as normal, but there will be a performance penalty when doing so on some systems. However, this protects you from having to manually reorganize files to the correct segment when you pass the `--resize-cluster` restore option to gprestore. You must use the `--backup-dir` option with this option.

`--single-data-file`
Optional. Create a single data file on each segment host for all tables backed up on that segment. By default, each `gpbackup` creates one compressed CSV file for each table that is backed up on the segment.

> **Note**
>
> If you use the `--single-data-file` option to combine table backups into a single file per segment, you cannot set the gprestore option `--jobs` to a value higher than 1 to perform a parallel restore operation.

`--verbose`
Optional. Print verbose log messages.

`--version`
Optional. Print the version number and exit.

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`--with-stats`
Optional. Include query plan statistics in the backup set.

`--without-globals`
Optional. Omit the global WarehousePG system objects during backup.

`--help`
Displays the online help.

Examples

To create the database `test` using the default options:

```
createdb test
```

To create the database `demo` using the WarehousePG coordinator on host `gpcoord`, port `54321`, using the `LATIN1` encoding scheme:

```
createdb -p 54321 -h gpcoord -E LATIN1 demo
```

See Also

gprestore

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7.7.2.10 gpcheckcat

The `gpcheckcat` utility tests WarehousePG catalog tables for inconsistencies.

The utility is in `$GPHOME/bin/lib`.

Synopsis

```
gpcheckcat [ <options<] [ <dbname>]

  Options:
     -g <dir>
     -p <port>
     -s <test_name | 'test_name1, test_name2 [, ...]'>
     -P <password>
     -U <user_name>
     -S {none | only}
     -O
     -R <test_name | 'test_name1, test_name2 [, ...]'>
     -C <catalog_name>
     -B <parallel_processes>
     -v
     -A
     -x "<parameter_name>=<value>"

gpcheckcat  -l

gpcheckcat -? | --help
```

Description

The `gpcheckcat` utility runs multiple tests that check for database catalog inconsistencies. Some of the tests cannot be run concurrently with other workload statements or the results will not be usable. Restart the database in restricted mode when running `gpcheckcat`, otherwise `gpcheckcat` might report inconsistencies due to ongoing database operations rather than the actual number of inconsistencies. If you run `gpcheckcat` without stopping database activity, run it with `-O` option.

> **Note**
>
> Any time you run the utility, it checks for and deletes orphaned, temporary database schemas (temporary schemas without a session ID) in the specified databases. The utility displays the results of the orphaned, temporary schema check on the command line and also logs the results.

Catalog inconsistencies are inconsistencies that occur between WarehousePG cluster tables. In general, there are three types of inconsistencies:

- Inconsistencies in system tables at the segment level. For example, an inconsistency between a system table that contains table data and a system table that contains column data. As another, a system table that contains duplicates in a column that should to be unique.
- Inconsistencies between same system table across segments. For example, a system table is missing row on one segment, but other segments have this row. As another example, the values of specific row column data are different across segments, such as table owner or table access privileges.
- Inconsistency between a catalog table and the filesystem. For example, a file exists in database directory, but there is no entry for it in the pg_class table.

Options

-A

Run `gpcheckcat` on all databases in the WarehousePG installation.

-B <parallel_processes>

The number of processes to run in parallel.

The `gpcheckcat` utility attempts to determine the number of simultaneous processes (the batch size) to use. The utility assumes it can use a buffer with a minimum of 20MB for each process. The maximum number of parallel processes is the number of WarehousePG segment instances. The utility displays the number of parallel processes that it uses when it starts checking the catalog.

> **Note**
>
> The utility might run out of memory if the number of errors returned exceeds the buffer size. If an out of memory error occurs, you can lower the batch size with the `-B` option. For example, if the utility displays a batch size of 936 and runs out of memory, you can specify `-B 468` to run 468 processes in parallel.

-C catalog_table

Run cross consistency, foreign key, and ACL tests for the specified catalog table.

-g data_directory

Generate SQL scripts to fix catalog inconsistencies. The scripts are placed in data_directory.

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-l

List the `gpcheckcat` tests.

-o

Run only the `gpcheckcat` tests that can be run in online (not restricted) mode.

-p port

This option specifies the port that is used by the WarehousePG.

-P password

The password of the user connecting to WarehousePG.

-R test_name | 'test_name1,test_name2 [, ...]'

Specify one or more tests to run. Specify multiple tests as a comma-delimited list of test names enclosed in quotes.

Some tests can be run only when WarehousePG is in restricted mode.

> **These are the tests that can be performed:**
>
> `acl` - Cross consistency check for access control privileges
>
> `aoseg_table` - Check that the vertical partition information (vpinfo) on segment instances is consistent with `pg_attribute` (checks only append-optimized, column storage tables in the database)
>
> `duplicate` - Check for duplicate entries
>
> `foreign_key` - Check foreign keys
>
> `inconsistent` - Cross consistency check for coordinator segment inconsistency
>
> `missing_extraneous` - Cross consistency check for missing or extraneous entries
>
> `mix_distribution_policy` - Check `pg_opclass` and `pg_amproc` to identify tables using a mix of legacy and non-legacy hashops in their distribution policies.
>
> `owner` - Check table ownership that is inconsistent with the coordinator database
>
> `orphaned_toast_tables` - Check for orphaned TOAST tables.
>
> `part_integrity` - Check *pg_partition* branch integrity, partition with OIDs, partition distribution policy
>
> `unique_index_violation` - Check tables that have columns with the unique index constraint for duplicate entries
>
> `dependency` - Check for dependency on non-existent objects (restricted mode only)
>
> `distribution_policy` - Check constraints on randomly distributed tables (restricted mode only)
>
> `namespace` - Check for schemas with a missing schema definition (restricted mode only)
>
> `pgclass` - Check *pg_class* entry that does not have any corresponding *pg_attribute* entry (restricted mode only)

> **Note**
>
> There are several ways a TOAST table can become orphaned where a repair script cannot be generated and a manual catalog change is required. One way is if the `reltoastrelid` entry in *pg_class* points to an incorrect TOAST table (a TOAST table mismatch). Another way is if both the `reltoastrelid` in *pg_class* is missing and the `pg_depend` entry is missing (a double orphan TOAST table). If a manual catalog change is needed, `gpcheckcat` will display detailed steps you can follow to update the catalog. Contact Support if you need help with the catalog change.

-s `test_name | 'test_name1, test_name2 [, ...]'`

Specify one ore more tests to skip. Specify multiple tests as a comma-delimited list of test names enclosed in quotes.

-S {none | only}

Specify this option to control the testing of catalog tables that are shared across all databases in the WarehousePG installation, such as *pg_database*.

The value `none` deactivates testing of shared catalog tables. The value `only` tests only the shared catalog tables.

-U user_name

The user connecting to WarehousePG.

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-? | --help

Displays the online help.

-v (verbose)

Displays detailed information about the tests that are performed.

-x `"<parameter_name>=<value>"`

Set a server configuration parameter, such as `log_min_messages`, at a session level. To set multiple configuration parameters, use the `-x` option multiple times.

Notes

The utility identifies tables with missing attributes and displays them in various locations in the output and in a non-standardized format. The utility also displays a summary list of tables with missing attributes in the format `<database>. <schema>. <table>. <segment_id>` after the output information is displayed.

If `gpcheckcat` detects inconsistent OID (Object ID) information, it generates one or more verification files that contain an SQL query. You can run the SQL query to see details about the OID inconsistencies and investigate the inconsistencies. The files are generated in the directory where `gpcheckcat` is invoked.

This is the format of the file:

```
gpcheckcat.verify.dbname.catalog\_table\_name.test\_name.TIMESTAMP.sql
```

This is an example verification filename created by `gpcheckcat` when it detects inconsistent OID (Object ID) information in the catalog table *pg_type* in the database `mydb`:

```
gpcheckcat.verify.mydb.pg_type.missing_extraneous.20150420102715.sql
```

This is an example query from a verification file:

```
SELECT *
  FROM (
       SELECT relname, oid FROM pg_class WHERE reltype
         IN (1305822,1301043,1301069,1301095)
       UNION ALL
       SELECT relname, oid FROM gp_dist_random('pg_class') WHERE reltype
         IN (1305822,1301043,1301069,1301095)
       ) alltyprelids
  GROUP BY relname, oid ORDER BY count(*) desc ;
```

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7.7.2.11 gpcheckperf

Verifies the baseline hardware performance of the specified hosts.

Synopsis

```
gpcheckperf -d <test_directory> [-d <test_directory> ...]
    {-f <hostfile_gpcheckperf> | - h <hostname> [-h hostname ...]}
    [-r ds] [-B <block_size>] [-S <file_size>] [--buffer-size <buffer_size>] [-D] [-v|-V]

gpcheckperf -d <temp_directory>
    {-f <hostfile_gpchecknet> | - h <hostname> [-h< hostname> ...]}
    [ -r n|N|M [--duration <time>] [--netperf] ] [-D] [-v | -V]

gpcheckperf -?

gpcheckperf --version
```

Description

The `gpcheckperf` utility starts a session on the specified hosts and runs the following performance tests:

- **Disk I/O Test (dd test)** — To test the sequential throughput performance of a logical disk or file system, the utility uses the **dd** command, which is a standard UNIX utility. It times how long it takes to write and read a large file to and from disk and calculates your disk I/O performance in megabytes (MB) per second. By default, the file size that is used for the test is calculated at two times the total random access memory (RAM) on the host. This ensures that the test is truly testing disk I/O and not using the memory cache.
- **Memory Bandwidth Test (stream)** — To test memory bandwidth, the utility uses the STREAM benchmark program to measure sustainable memory bandwidth (in MB/s). This tests that your system is not limited in performance by the memory bandwidth of the system in relation to the computational performance of the CPU. In applications where the data set is large (as in WarehousePG), low memory bandwidth is a major performance issue. If memory bandwidth is significantly lower than the theoretical bandwidth of the CPU, then it can cause the CPU to spend significant amounts of time waiting for data to arrive from system memory.
- **Network Performance Test (gpnetbench*)** — To test network performance (and thereby the performance of the WarehousePG interconnect), the utility runs a network benchmark program that transfers a 5 second stream of data from the current host to each remote host included in the test. The data is transferred in parallel to each remote host and the minimum, maximum, average and median network transfer rates are reported in megabytes (MB) per second. If the summary transfer rate is slower than expected (less than 100 MB/s), you can run the network test serially using the `-r n` option to obtain per-host results. To run a full-matrix bandwidth test, you can specify `-r M` which will cause every host to send and receive data from every other host specified. This test is best used to validate if the switch fabric can tolerate a full-matrix workload.

To specify the hosts to test, use the `-f` option to specify a file containing a list of host names, or use the `-h` option to name single host names on the command-line. If running the network performance test, all entries in the host file must be for network interfaces within the same subnet. If your segment hosts have multiple network interfaces configured on different subnets, run the network test once for each subnet.

You must also specify at least one test directory (with `-d`). The user who runs `gpcheckperf` must have write access to the specified test directories on all remote hosts. For the disk I/O test, the test directories should correspond to your segment data directories (primary and/or mirrors). For the memory bandwidth and network tests, a temporary directory is required for the test program files.

Before using `gpcheckperf`, you must have a trusted host setup between the hosts involved in the performance test. You can use the utility `gpssh-exkeys` to update the known host files and exchange public keys between hosts if you have not done so already. Note that `gpcheckperf` calls to `gpssh` and `gpsync`, so these WarehousePG utilities must also be in your `$PATH`.

Options

-B block_size

Specifies the block size (in KB or MB) to use for disk I/O test. The default is 32KB, which is the same as the WarehousePG page size. The maximum block size is 1 MB.

--buffer-size buffer_size

Specifies the size of the send buffer in kilobytes. The default size is 8 kilobytes.

> **Note** If you want to compare network performance between WarehousePG 6 and WarehousePG 7, set `--buffer-size` to 32KB in WarehousePG 7 to make it consistent with the default WarehousePG 6 buffer size.

-d test_directory

For the disk I/O test, specifies the file system directory locations to test. You must have write access to the test directory on all hosts involved in the performance test. You can use the `-d` option multiple times to specify multiple test directories (for example, to test disk I/O of your primary and mirror data directories).

-d temp_directory

For the network and stream tests, specifies a single directory where the test program files will be copied for the duration of the test. You must have write access to this directory on all hosts involved in the test.

-D (display per-host results)

Reports performance results for each host for the disk I/O tests. The default is to report results for just the hosts with the minimum and maximum performance, as well as the total and average performance of all hosts.

--duration time

Specifies the duration of the network test in seconds (s), minutes (m), hours (h), or days (d). The default is 15 seconds.

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-f hostfile_gpcheckperf

For the disk I/O and stream tests, specifies the name of a file that contains one host name per host that will participate in the performance test. The host name is required, and you can optionally specify an alternate user name and/or SSH port number per host. The syntax of the host file is one host per line as follows:

```
[<username>@]<hostname>[:<ssh_port>]
```

-f hostfile_gpchecknet

For the network performance test, all entries in the host file must be for host addresses within the same subnet. If your segment hosts have multiple network interfaces configured on different subnets, run the network test once for each subnet. For example (a host file containing segment host address names for interconnect subnet 1):

```
sdw1-1
sdw2-1
sdw3-1
```

-h hostname

Specifies a single host name (or host address) that will participate in the performance test. You can use the `-h` option multiple times to specify multiple host names.

--netperf

Specifies that the `netperf` binary should be used to perform the network test instead of the WarehousePG network test. To use this option, you must download `netperf` from https://github.com/HewlettPackard/netperf and install it into `$GPHOME/bin/lib` on all WarehousePG hosts (coordinator and segments).

-r ds{n|N|M}

Specifies which performance tests to run. The default is `dsn`:

```
-   Disk I/O test \(`d`\)
-   Stream test \(`s`\)
-   Network performance test in sequential \(`n`\), parallel \(`N`\), or full-matrix \(`M`\) mode. The optional `--duration` option specifies how long \(in
seconds\) to run the network test. To use the parallel \(`N`\) mode, you must run the test on an even number of hosts.
    <br/><br/>If you would rather use `netperf` \([https://github.com/HewlettPackard/netperf](https://github.com/HewlettPackard/netperf)\) instead of the
WarehousePG network test, you can download it and install it into `$GPHOME/bin/lib` on all WarehousePG hosts \(coordinator and segments\). You would then specify
the optional `--netperf` option to use the `netperf` binary instead of the default `gpnetbench*` utilities.
```

-S file_size

Specifies the total file size to be used for the disk I/O test for all directories specified with `-d`. file_size should equal two times total RAM on the host. If not specified, the default is calculated at two times the total RAM on the host where `gpcheckperf` is run. This ensures that the test is truly testing disk I/O and not using the memory cache. You can specify sizing in KB, MB, or GB.

-v (verbose) | -V (very verbose)

Verbose mode shows progress and status messages of the performance tests as they are run. Very verbose mode shows all output messages generated by this utility.

--version

Displays the version of this utility.

-? (help)

Displays the online help.

Examples

Run the disk I/O and memory bandwidth tests on all the hosts in the file host_file using the test directory of /data1 and /data2:

```
$ gpcheckperf -f hostfile_gpcheckperf -d /data1 -d /data2 -r ds
```

Run only the disk I/O test on the hosts named sdw1 and sdw2using the test directory of /data1. Show individual host results and run in verbose mode:

```
$ gpcheckperf -h sdw1 -h sdw2 -d /data1 -r d -D -v
```

Run the parallel network test using the test directory of /tmp, where hostfile_gpcheck_ic* specifies all network interface host address names within the same interconnect subnet:

```
$ gpcheckperf -f hostfile_gpchecknet_ic1 -r N -d /tmp
$ gpcheckperf -f hostfile_gpchecknet_ic2 -r N -d /tmp
```

Run the same test as above, but use `netperf` instead of the WarehousePG network test (note that `netperf` must be installed in `$GPHOME/bin/lib` on all WarehousePG hosts):

```
$ gpcheckperf -f hostfile_gpchecknet_ic1 -r N --netperf -d /tmp
$ gpcheckperf -f hostfile_gpchecknet_ic2 -r N --netperf -d /tmp
```

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See Also

gpssh, gpsync

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7.7.2.12 gpconfig

Sets server configuration parameters on all segments within a WarehousePG cluster.

Synopsis

```
gpconfig -c <param_name> -v <value> [-m <coordinator_value> | --coordinatoronly]
       | -r <param_name> [--coordinatoronly]
       | -l
       [--skipvalidation] [--verbose] [--debug]

gpconfig -s <param_name> [--file | --file-compare] [--verbose] [--debug]

gpconfig --help
```

Description

The `gpconfig` utility allows you to set, unset, or view configuration parameters from the `postgresql.conf` files of all instances (coordinator, segments, and mirrors) in your WarehousePG cluster. When setting a parameter, you can also specify a different value for the coordinator if necessary. For example, parameters such as `max_connections` require a different setting on the coordinator than what is used for the segments. If you want to set or unset a global or coordinator only parameter, use the `--coordinatoronly` option.

> **Note** For configuration parameters of vartype `string`, you may not pass values enclosed in single quotes to `gpconfig -c`.

`gpconfig` can only be used to manage certain parameters. For example, you cannot use it to set parameters such as `port`, which is required to be distinct for every segment instance. Use the `-l` (list) option to see a complete list of configuration parameters supported by `gpconfig`.

When `gpconfig` sets a configuration parameter in a segment `postgresql.conf` file, the new parameter setting always displays at the bottom of the file. When you use `gpconfig` to remove a configuration parameter setting, `gpconfig` comments out the parameter in all segment `postgresql.conf` files, thereby restoring the system default setting. For example, if you use `gpconfig` to remove (comment out) a parameter and later add it back (set a new value), there will be two instances of the parameter; one that is commented out, and one that is enabled and inserted at the bottom of the `postgresql.conf` file.

After setting a parameter, you must restart your WarehousePG cluster or reload the `postgresql.conf` files in order for the change to take effect. Whether you require a restart or a reload depends on the parameter.

For more information about the server configuration parameters, see the *WarehousePG Reference Guide*.

To show the currently set values for a parameter across the system, use the `-s` option.

`gpconfig` uses the following environment variables to connect to the WarehousePG coordinator instance and obtain system configuration information:

- `PGHOST`
- `PGPORT`
- `PGUSER`
- `PGPASSWORD`
- `PGDATABASE`

Options

-c | --change param_name Changes a configuration parameter setting by adding the new setting to the bottom of the `postgresql.conf` files.

-v | --value value The value to use for the configuration parameter you specified with the `-c` option. By default, this value is applied to all segments, their mirrors, the coordinator, and the standby coordinator.

The utility correctly quotes the value when adding the setting to the `postgresql.conf` files.

To set the value to an empty string, enter empty single quotes (`''`).

-m | --coordinatorvalue coordinator_value The coordinator value to use for the configuration parameter you specified with the `-c` option. If specified, this value only applies to the coordinator and standby coordinator. This option can only be used with `-v`.

--coordinatoronly When specified, `gpconfig` will only edit the coordinator `postgresql.conf` file.

-r | --remove param_name Removes a configuration parameter setting by commenting out the entry in the `postgresql.conf` files.

-l | --list Lists all configuration parameters supported by the `gpconfig` utility.

-s | --show param_name Shows the value for a configuration parameter used on all instances (coordinator and segments) in the WarehousePG cluster. If there is a difference in a parameter value among the instances, the utility displays an error message. Running `gpconfig` with the `-s` option reads parameter values directly from the database, and not the `postgresql.conf` file. If you are using `gpconfig` to set configuration parameters across all segments, then running `gpconfig -s` to verify the changes, you might still see the previous (old) values. You must reload the configuration files (`gpstop -u`) or restart the system (`gpstop -r`) for changes to take effect.

--file For a configuration parameter, shows the value from the `postgresql.conf` file on all instances (coordinator and segments) in the WarehousePG cluster. If there is a difference in a parameter value among the instances, the utility displays a message. Must be specified with the `-s` option.

For example, the configuration parameter `statement_mem` is set to 64MB for a user with the `ALTER ROLE` command, and the value in the `postgresql.conf` file is 128MB. Running the command `gpconfig -s statement_mem --file` displays 128MB. The command `gpconfig -s statement_mem` run by the user displays 64MB.

Not valid with the `--file-compare` option.

--file-compare For a configuration parameter, compares the current WarehousePG value with the value in the `postgresql.conf` files on hosts (coordinator and segments). The values in the `postgresql.conf files` represent the value when WarehousePG is restarted.

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If the values are not the same, the utility displays the values from all hosts. If all hosts have the same value, the utility displays a summary report.

Not valid with the `--file` option.

--skipvalidation Overrides the system validation checks of `gpconfig` and allows you to operate on any server configuration parameter, including hidden parameters and restricted parameters that cannot be changed by `gpconfig`. When used with the `-l` option (list), it shows the list of restricted parameters.

```
> **Caution** Use extreme caution when setting configuration parameters with this option.
```

--verbose Displays additional log information during `gpconfig` command execution.

--debug Sets logging output to debug level.

-? | -h | --help Displays the online help.

Examples

Set the `max_connections` setting to 100 on all segments and 10 on the coordinator:

```
gpconfig -c max_connections -v 100 -m 10
```

These examples shows the syntax required due to bash shell string processing.

```
gpconfig -c search_path -v '"\$user",public'
gpconfig -c dynamic_library_path -v '\$libdir'
```

The configuration parameters are added to the `postgresql.conf` file.

```
search_path='"$user",public'
dynamic_library_path='$libdir'
```

Comment out all instances of the `default_statistics_target` configuration parameter, and restore the system default:

```
gpconfig -r default_statistics_target
```

List all configuration parameters supported by `gpconfig`:

```
gpconfig -l
```

Show the values of a particular configuration parameter across the system:

```
gpconfig -s max_connections
```

See Also

gpstop

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7.7.2.13 gpdeletesystem

Deletes a WarehousePG cluster that was initialized using `gpinitsystem`.

Synopsis

```
gpdeletesystem [-d <coordinator_data_directory>] [-B <parallel_processes>]
   [-f] [-l <logfile_directory>] [-D]

gpdeletesystem -?

gpdeletesystem -v
```

Description

The `gpdeletesystem` utility performs the following actions:

- Stop all `postgres` processes (the segment instances and coordinator instance).
- Deletes all data directories.

Before running `gpdeletesystem`:

- Move any backup files out of the coordinator and segment data directories.
- Make sure that WarehousePG is running.
- If you are currently in a segment data directory, change directory to another location. The utility fails with an error when run from within a segment data directory.

This utility will not uninstall the WarehousePG software.

Options

-d coordinator_data_directory Specifies the coordinator host data directory. If this option is not specified, the setting for the environment variable `COORDINATOR_DATA_DIRECTORY` is used. If this option is specified, it overrides any setting of `COORDINATOR_DATA_DIRECTORY`. If coordinator_data_directory cannot be determined, the utility returns an error.

-B parallel_processes The number of segments to delete in parallel. If not specified, the utility will start up to 60 parallel processes depending on how many segment instances it needs to delete.

-f (force) Force a delete even if backup files are found in the data directories. The default is to not delete WarehousePG instances if backup files are present.

-l logfile_directory The directory to write the log file. Defaults to `~/gpAdminLogs`.

-D (debug) Sets logging level to debug.

-? (help) Displays the online help.

-v (show utility version) Displays the version, status, last updated date, and check sum of this utility.

Examples

Delete a WarehousePG cluster:

```
gpdeletesystem -d /gpdata/gp-1
```

Delete a WarehousePG cluster even if backup files are present:

```
gpdeletesystem -d /gpdata/gp-1 -f
```

See Also

gpinitsystem

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7.7.2.14 gpexpand

Expands an existing WarehousePG across new hosts in the system.

Synopsis

```
gpexpand [{-f|--hosts-file} <hosts_file>]
        | {-i|--input} <input_file> [-B <batch_size>]
        | [{-d | --duration} <hh:mm:ss> | {-e|--end} '<YYYY-MM-DD hh:mm:ss>']
          [-a|-analyze]
          [-n  <parallel_processes>]
        | {-r|--rollback}
        | {-c|--clean}
        [-v|--verbose] [-s|--silent]
        [{-t|--tardir} <directory> ]
        [-S|--simple-progress ]

gpexpand -? | -h | --help

gpexpand --version
```

Prerequisites

- You are logged in as the WarehousePG superuser (`gpadmin`).
- The new segment hosts have been installed and configured as per the existing segment hosts. This involves:
  - Configuring the hardware and OS
  - Installing the WarehousePG software
  - Creating the `gpadmin` user account
  - Exchanging SSH keys.

- Enough disk space on your segment hosts to temporarily hold a copy of your largest table.
- When redistributing data, WarehousePG must be running in production mode. WarehousePG cannot be running in restricted mode or in coordinator mode. The `gpstart` options `-R` or `-m` cannot be specified to start WarehousePG.

> **Note** These utilities cannot be run while `gpexpand` is performing segment initialization.

- `gpbackup`
- `gpcheckcat`
- `gpconfig`
- `gprestore`

> **Important** When expanding a WarehousePG cluster, you must deactivate WarehousePG interconnect proxies before adding new hosts and segment instances to the system, and you must update the `gp_interconnect_proxy_addresses` parameter with the newly-added segment instances before you re-enable interconnect proxies. For information about WarehousePG interconnect proxies, see Configuring Proxies for the WarehousePG Interconnect.

For information about preparing a system for expansion, see Expanding a WarehousePG cluster in the *WarehousePG Administrator Guide*.

Description

The `gpexpand` utility performs system expansion in two phases: segment instance initialization and then table data redistribution.

In the initialization phase, `gpexpand` runs with an input file that specifies data directories, dbid values, and other characteristics of the new segment instances. You can create the input file manually, or by following the prompts in an interactive interview.

If you choose to create the input file using the interactive interview, you can optionally specify a file containing a list of expansion system hosts. If your platform or command shell limits the length of the list of hostnames that you can type when prompted in the interview, specifying the hosts with `-f` may be mandatory.

In addition to initializing the segment instances, the initialization phase performs these actions:

- Creates an expansion schema named *gpexpand* in the postgres database to store the status of the expansion operation, including detailed status for tables.

In the table data redistribution phase, `gpexpand` redistributes table data to rebalance the data across the old and new segment instances.

> **Note** Data redistribution should be performed during low-use hours. Redistribution can be divided into batches over an extended period.

To begin the redistribution phase, run `gpexpand` with no options or with the `-d` (duration), `-e` (end time), or `-i` options. If you specify an end time or duration, then the utility redistributes tables in the expansion schema until the specified end time or duration is reached. If you specify `-i` or no options, then the utility redistribution phase continues until all tables in the expansion schema are reorganized. Each table is reorganized using `ALTER TABLE` commands to rebalance the tables across new segments, and to set tables to their original distribution policy. If `gpexpand` completes the reorganization of all tables, it displays a success message and ends.

> **Note** This utility uses secure shell (SSH) connections between systems to perform its tasks. In large WarehousePG deployments, cloud deployments, or deployments with a large number of segments per host, this utility may exceed the host's maximum threshold for unauthenticated connections. Consider updating the SSH `MaxStartups` and `MaxSessions` configuration parameters to increase this threshold. For more information about SSH configuration options, refer to the SSH documentation for your Linux distribution.

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Options

-a | --analyze Run `ANALYZE` to update the table statistics after expansion. The default is to not run `ANALYZE`.

-B batch_size Batch size of remote commands to send to a given host before making a one-second pause. Default is `16`. Valid values are 1-128.

The `gpexpand` utility issues a number of setup commands that may exceed the host's maximum threshold for unauthenticated connections as defined by `MaxStartups` in the SSH daemon configuration. The one-second pause allows authentications to be completed before `gpexpand` issues any more commands.

The default value does not normally need to be changed. However, it may be necessary to reduce the maximum number of commands if `gpexpand` fails with connection errors such as `'ssh_exchange_identification: Connection closed by remote host.'`

-c | --clean Remove the expansion schema.

-d | --duration hh:mm:ss Duration of the expansion session from beginning to end.

-e | --end 'YYYY-MM-DD hh:mm:ss' Ending date and time for the expansion session.

-f | --hosts-file filename Specifies the name of a file that contains a list of new hosts for system expansion. Each line of the file must contain a single host name.

This file can contain hostnames with or without network interfaces specified. The `gpexpand` utility handles either case, adding interface numbers to end of the hostname if the original nodes are configured with multiple network interfaces.

```
> **Note** The WarehousePG segment host naming convention is `sdwN` where `sdw` is a prefix and `N` is an integer. For example, `sdw1`, `sdw2` and so on. For hosts with multiple interfaces, the convention is to append a dash \(`-`\) and number to the host name. For example, `sdw1-1` and `sdw1-2` are the two interface names for host `sdw1`.
```

For information about using a hostname or IP address, see Specifying Hosts using Hostnames or IP Addresses. Also, see Using Host Systems with Multiple NICs.

-i | --input input_file Specifies the name of the expansion configuration file, which contains one line for each segment to be added in the format of:

hostname|address|port|datadir|dbid|content|preferred_role

-n parallel_processes The number of tables to redistribute simultaneously. Valid values are 1 - 96.

Each table redistribution process requires two database connections: one to alter the table, and another to update the table's status in the expansion schema. Before increasing `-n`, check the current value of the server configuration parameter `max_connections` and make sure the maximum connection limit is not exceeded.

-r | --rollback Roll back a failed expansion setup operation.

-s | --silent Runs in silent mode. Does not prompt for confirmation to proceed on warnings.

-S | --simple-progress If specified, the `gpexpand` utility records only the minimum progress information in the WarehousePG table *gpexpand.expansion_progress*. The utility does not record the relation size information and status information in the table *gpexpand.status_detail*.

Specifying this option can improve performance by reducing the amount of progress information written to the *gpexpand* tables.

[-t | --tardir] directory The fully qualified path to a directory on segment hosts where the `gpexpand` utility copies a temporary tar file. The file contains WarehousePG files that are used to create segment instances. The default directory is the user home directory.

-v | --verbose Verbose debugging output. With this option, the utility will output all DDL and DML used to expand the database.

--version Display the utility's version number and exit.

-? | -h | --help Displays the online help.

Specifying Hosts using Hostnames or IP Addresses

When expanding a WarehousePG cluster, you can specify either a hostname or an IP address for the value.

- If you specify a hostname, the resolution of the hostname to an IP address should be done locally for security. For example, you should use entries in a local `/etc/hosts` file to map a hostname to an IP address. The resolution of a hostname to an IP address should not be performed by an external service such as a public DNS server. You must stop the WarehousePG cluster before you change the mapping of a hostname to a different IP address.
- If you specify an IP address, the address should not be changed after the initial configuration. When segment mirroring is enabled, replication from the primary to the mirror segment will fail if the IP address changes from the configured value. For this reason, you should use a hostname when expanding a WarehousePG cluster unless you have a specific requirement to use IP addresses.

When expanding a WarehousePG cluster, `gpexpand` populates gp_segment_configuration catalog table with the new segment instance information. WarehousePG uses the `address` value of the `gp_segment_configuration` catalog table when looking up host systems for WarehousePG interconnect (internal) communication between the coordinator and segment instances and between segment instances, and for other internal communication.

Using Host Systems with Multiple NICs

If host systems are configured with multiple NICs, you can expand a WarehousePG cluster to use each NIC as a WarehousePG host system. You must ensure that the host systems are configured with sufficient resources to support all the segment instances being added to the host. Also, if you enable segment mirroring, you must ensure that the expanded WarehousePG cluster configuration supports failover if a host system fails. For information about WarehousePG mirroring schemes, see ../../best_practices/ha.html#topic_ngz_qf4_tt.

For example, this is a `gpexpand` configuration file for a simple WarehousePG cluster. The segment host `gp7s1` and `gp7s2` are configured with two NICs, `-s1` and `-s2`, where the WarehousePG cluster uses each NIC as a host system.

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```
gp7s1-s2|gp7s1-s2|40001|/data/data1/gpseg2|6|2|p
gp7s2-s1|gp7s2-s1|50000|/data/mirror1/gpseg2|9|2|m
gp7s2-s1|gp7s2-s1|40000|/data/data1/gpseg3|7|3|p
gp7s1-s2|gp7s1-s2|50001|/data/mirror1/gpseg3|8|3|m
```

Examples

Run `gpexpand` with an input file to initialize new segments and create the expansion schema in the postgres database:

```
$ gpexpand -i input_file
```

Run `gpexpand` for sixty hours maximum duration to redistribute tables to new segments:

```
$ gpexpand -d 60:00:00
```

See Also

gpssh-exkeys, Expanding a WarehousePG cluster

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7.7.2.15 gpfdist

Serves data files to or writes data files out from WarehousePG segments.

Synopsis

```
gpfdist [-d <directory>] [-p <http_port>] [-P <last_http_port>] [-l <log_file>]
   [-t <timeout>] [-k <clean_up_timeout>] [-S] [-w <time>] [-v | -V] [-s] [-m <max_length>]
   [--ssl <certificate_path> [--ssl_verify_peer <boolean>] [--sslclean <wait_time>] ]
   [--compress] [--multi_thread <num_threads>]
   [-c <config.yml>]

gpfdist -? | --help

gpfdist --version
```

Description

`gpfdist` is WarehousePG parallel file distribution program. It is used by readable external tables and `gpload` to serve external table files to all WarehousePG segments in parallel. It is used by writable external tables to accept output streams from WarehousePG segments in parallel and write them out to a file.

> **Note** `gpfdist` and `gpload` are compatible only with the WarehousePG major version in which they are shipped. For example, a `gpfdist` utility that is installed with WarehousePG 6.x cannot be used with WarehousePG 7.x.

In order for `gpfdist` to be used by an external table, the `LOCATION` clause of the external table definition must specify the external table data using the `gpfdist://` protocol (see the WarehousePG command `CREATE EXTERNAL TABLE`).

> **Note** If you specify the `--ssl` option to enable SSL security, you must create the external table with the `gpfdists://` protocol.

The benefit of using `gpfdist` is that you are guaranteed maximum parallelism while reading from or writing to external tables, thereby offering the best performance as well as easier administration of external tables.

For readable external tables, `gpfdist` parses and serves data files evenly to all the segment instances in the WarehousePG cluster when users `SELECT` from the external table. For writable external tables, `gpfdist` accepts parallel output streams from the segments when users `INSERT` into the external table, and writes to an output file.

> **Note** When `gpfdist` reads data and encounters a data formatting error, the error message includes a row number indicating the location of the formatting error. `gpfdist` attempts to capture the row that contains the error. However, `gpfdist` might not capture the exact row for some formatting errors.

For readable external tables, if load files are compressed using `gzip` or `bzip2` (have a `.gz` or `.bz2` file extension), `gpfdist` uncompresses the data while loading the data (on the fly). For writable external tables, `gpfdist` compresses the data using `gzip` if the target file has a `.gz` extension.

> **Note** Compression is not supported for readable and writeable external tables when the `gpfdist` utility runs on Windows platforms.

When reading or writing data with the `gpfdist` or `gpfdists` protocol, WarehousePG includes `X-GP-PROTO` in the HTTP request header to indicate that the request is from WarehousePG. The utility rejects HTTP requests that do not include `X-GP-PROTO` in the request header.

Most likely, you will want to run `gpfdist` on your ETL machines rather than the hosts where WarehousePG is installed. To install `gpfdist` on another host, simply copy the utility over to that host and add `gpfdist` to your `$PATH`.

> **Note** When using IPv6, always enclose the numeric IP address in brackets.

Options

-d directory The directory from which `gpfdist` will serve files for readable external tables or create output files for writable external tables. If not specified, defaults to the current directory.

-l log_file The fully qualified path and log file name where standard output messages are to be logged.

-p http_port The HTTP port on which `gpfdist` will serve files. Defaults to 8080.

-P last_http_port The last port number in a range of HTTP port numbers (http_port to last_http_port, inclusive) on which `gpfdist` will attempt to serve files. `gpfdist` serves the files on the first port number in the range to which it successfully binds.

-t timeout Sets the time allowed for WarehousePG to establish a connection to a `gpfdist` process. Default is 5 seconds. Allowed values are 2 to 7200 seconds (2 hours). May need to be increased on systems with a lot of network traffic.

-k clean_up_timeout Sets the number of seconds that `gpfdist` waits before cleaning up the session when there are no `POST` requests from the segments. Default is 300. Allowed values are 300 to 86400. You may increase this value when experiencing heavy network traffic.

-m max_length Sets the maximum allowed data row length in bytes. Default is 32768. Should be used when user data includes very wide rows (or when `line too long` error message occurs). Should not be used otherwise as it increases resource allocation. Valid range is 32K to 256MB. The upper limit is 1MB on Windows systems.

> **Note** Memory issues might occur if you specify a large maximum row length and run a large number of `gpfdist` concurrent connections. For example, setting this value to the maximum of 256MB with 96 concurrent `gpfdist` processes requires approximately 24GB of memory (`(96 + 1) x 246MB`).

-s Enables simplified logging. When this option is specified, only messages with `WARN` level and higher are written to the `gpfdist` log file. `INFO` level messages are not written to the log file. If this option is not specified, all `gpfdist` messages are written to the log file.

You can specify this option to reduce the information written to the log file.

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-S (use O_SYNC) Opens the file for synchronous I/O with the `O_SYNC` flag. Any writes to the resulting file descriptor block `gpfdist` until the data is physically written to the underlying hardware.

-w time Sets the number of seconds that WarehousePG delays before closing a target file such as a named pipe. The default value is 0, no delay. The maximum value is 7200 seconds (2 hours).

For a WarehousePG with multiple segments, there might be a delay between segments when writing data from different segments to the file. You can specify a time to wait before WarehousePG closes the file to ensure all the data is written to the file.

--ssl certificate_path Prompts `gpfdist` to use SSL encryption for the data transfer. After running `gpfdist` with the `--ssl <certificate_path>` option, you must use the `gpfdists://` protocol to load data from this file server. For information on `gpfdists`, refer to gpfdists:// Protocol in the *WarehousePG Administrator Guide*.

The setting of the `--ssl_verify_peer` option determines which of the following files are required in the file system location specified by certificate_path:

```
-   The server certificate file, `server.crt`
-   The server private key file, `server.key`
-   The trusted certificate authorities, `root.crt`
```

The settings of both the verify_gpfdists_cert server configuration parameter and the `--ssl_verify_peer` option also determine which certificate files are required on the WarehousePG segments as described ingpfdists:// Protocol.

You cannot specify the root directory (`/`) as the certificate_path.

--ssl_verify_peer boolean When the `--ssl` option is also provided, specifies whether `gpfdist` enables or disables SSL certificate authentication on the WarehousePG side. The default value is `on` ; `gpfdist` checks the identities of clients, and requires that the `root.crt` , `server.crt` , and `server.key` be present in the certificate_path specified. When set to `off` , `gpfdist` does not check the identities of clients, and requires that only the `server.crt` and `server.key` be present in the `--ssl <certificate_path>` specified. The certificate authority file `root.crt` is not required.

--sslclean wait_time When the utility is run with the `--ssl` option, sets the number of seconds that the utility delays before closing an SSL session and cleaning up the SSL resources after it completes writing data to or from a WarehousePG segment. The default value is 0, no delay. The maximum value is 500 seconds. If the delay is increased, the transfer speed decreases.

In some cases, this error might occur when copying large amounts of data: `gpfdist server closed connection` . To avoid the error, you can add a delay, for example `--sslclean 5` .

--compress Enable compression during data transfer. When specified, `gpfdist` utilizes the Zstandard (`zstd`) compression algorithm. This option is not available on Windows platforms.

--multi_threads num_threads Sets the maximum number of threads that `gpfdist` uses during data transfer, parallelizing the operation. When specified, `gpfdist` automatically compresses the data (also parallelized) before transferring. `gpfdist` supports a maximum of 256 threads. This option is not available on Windows platforms.

-c config.yaml Specifies rules that `gpfdist` uses to select a transform to apply when loading or extracting data. The `gpfdist` configuration file is a YAML 1.1 document.

For information about the file format, see Configuration File Format in the *WarehousePG Administrator Guide*. For information about configuring data transformation with `gpfdist` , see Transforming External Data with gpfdist and gpload in the *WarehousePG Administrator Guide*.

This option is not available on Windows platforms.

-v (verbose) Verbose mode shows progress and status messages.

-V (very verbose) Verbose mode shows all output messages generated by this utility.

-? (help) Displays the online help.

--version Displays the version of this utility.

Notes

You can set the server configuration parameter gpfdist_retry_timeout to control the time that WarehousePG waits before returning an error when a `gpfdist` server does not respond while WarehousePG is attempting to write data to `gpfdist` . The default is 300 seconds (5 minutes).

If the `gpfdist` utility hangs with no read or write activity occurring, you can generate a core dump the next time a hang occurs to help debug the issue. Set the environment variable `GPFDIST_WATCHDOG_TIMER` to the number of seconds of no activity to wait before `gpfdist` is forced to exit. When the environment variable is set and `gpfdist` hangs, the utility is stopped after the specified number of seconds, creates a core dump, and sends relevant information to the log file.

This example sets the environment variable on a Linux system so that `gpfdist` exits after 300 seconds (5 minutes) of no activity.

```
export GPFDIST_WATCHDOG_TIMER=300
```

When you enable compression, `gpfdist` transmits a larger amount of data while maintaining low network usage. Note that compression can be time-intensive, and may potentially reduce transmission speeds. When you utilize multi-threaded execution, the overall time required for compression may decrease, which facilitates faster data transmission while maintaining low network occupancy and high speed.

Examples

To serve files from a specified directory using port 8081 (and start `gpfdist` in the background):

```
gpfdist -d /var/load_files -p 8081 &
```

To start `gpfdist` in the background and redirect output and errors to a log file:

```
gpfdist -d /var/load_files -p 8081 -l /home/gpadmin/log &
```

To enable multi-threaded data transfer (with implicit compression) using four threads, start `gpfdist` as follows:

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```
gpfdist -d /var/load_files -p 8081 --multi_thread 4
```

To enable SSL certificate authentication without peer verification, start `gpfdist` as follows:

```
gpfdist -d /var/load_files -p 8081 --ssl /path/to/certs --ssl_verify_peer off
```

To stop `gpfdist` when it is running in the background:

--First find its process id:

```
ps ax | grep gpfdist
```

--Then stop the process, for example:

```
kill 3456
```

See Also

gpload, `CREATE EXTERNAL TABLE`

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7.7.2.16 gpinitstandby

Adds and/or initializes a standby coordinator host for a WarehousePG cluster.

Synopsis

```
gpinitstandby { -s <standby_hostname> [-P port] | -r | -n } [-a] [-q]
    [-D] [-S <standby_data_directory>] [-l <logfile_directory>]
    [--hba-hostnames <boolean>]

gpinitstandby -v

gpinitstandby -?
```

Description

The `gpinitstandby` utility adds a backup, standby coordinator instance to your WarehousePG cluster. If your system has an existing standby coordinator instance configured, use the `-r` option to remove it before adding the new standby coordinator instance.

Before running this utility, make sure that the WarehousePG software is installed on the standby coordinator host and that you have exchanged SSH keys between the hosts. It is recommended that the coordinator port is set to the same port number on the coordinator host and the standby coordinator host.

This utility should be run on the currently active *primary* coordinator host. See the *WarehousePG Installation Guide* for instructions.

The utility performs the following steps:

- Updates the WarehousePG cluster catalog to remove the existing standby coordinator information (if the `-r` option is supplied)
- Updates the WarehousePG cluster catalog to add the new standby coordinator instance information
- Edits the `pg_hba.conf` file of the WarehousePG coordinator to allow access from the newly added standby coordinator
- Sets up the standby coordinator instance on the alternate coordinator host
- Starts the synchronization process

A backup, standby coordinator instance serves as a 'warm standby' in the event of the primary coordinator becoming non-operational. The standby coordinator is kept up to date by transaction log replication processes (the `walsender` and `walreceiver`), which run on the primary coordinator and standby coordinator hosts and keep the data between the primary and standby coordinator instances synchronized. If the primary coordinator fails, the log replication process is shut down, and the standby coordinator can be activated in its place by using the `gpactivatestandby` utility. Upon activation of the standby coordinator, the replicated logs are used to reconstruct the state of the coordinator instance at the time of the last successfully committed transaction.

The activated standby coordinator effectively becomes the WarehousePG coordinator, accepting client connections on the coordinator port and performing normal coordinator operations such as SQL command processing and resource management.

> **Important** If the `gpinitstandby` utility previously failed to initialize the standby coordinator, you must delete the files in the standby coordinator data directory before running `gpinitstandby` again. The standby coordinator data directory is not cleaned up after an initialization failure because it contains log files that can help in determining the reason for the failure.

If an initialization failure occurs, a summary report file is generated in the standby host directory `/tmp`. The report file lists the directories on the standby host that require clean up.

Options

-a (do not prompt) Do not prompt the user for confirmation.

-D (debug) Sets logging level to debug.

--hba-hostnames boolean Optional. Controls whether this utility uses IP addresses or host names in the `pg_hba.conf` file when updating this file with addresses that can connect to WarehousePG. When set to 0 -- the default value -- this utility uses IP addresses when updating this file. When set to 1, this utility uses host names when updating this file. For consistency, use the same value that was specified for `HBA_HOSTNAMES` when the WarehousePG cluster was initialized. For information about how WarehousePG resolves host names in the `pg_hba.conf` file, see Configuring Client Authentication.

-l logfile_directory The directory to write the log file. Defaults to `~/gpAdminLogs`.

-n (restart standby coordinator) Specify this option to start a WarehousePG standby coordinator that has been configured but has stopped for some reason.

-P port This option specifies the port that is used by the WarehousePG standby coordinator. The default is the same port used by the active WarehousePG coordinator.

If the WarehousePG standby coordinator is on the same host as the active coordinator, the ports must be different. If the ports are the same for the active and standby coordinator and the host is the same, the utility returns an error.

-q (no screen output) Run in quiet mode. Command output is not displayed on the screen, but is still written to the log file.

-r (remove standby coordinator) Removes the currently configured standby coordinator instance from your WarehousePG cluster.

-s standby_hostname The host name of the standby coordinator host.

-S standby_data_directory The data directory to use for a new standby coordinator. The default is the same directory used by the active coordinator.

If the standby coordinator is on the same host as the active coordinator, a different directory must be specified using this option.

-v (show utility version) Displays the version, status, last updated date, and checksum of this utility.

-? (help) Displays the online help.

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Examples

Add a standby coordinator instance to your WarehousePG cluster and start the synchronization process:

```
gpinitstandby -s host09
```

Start an existing standby coordinator instance and synchronize the data with the current primary coordinator instance:

```
gpinitstandby -n
```

> **Note** Do not specify the -n and -s options in the same command.

Add a standby coordinator instance to your WarehousePG cluster specifying a different port:

```
gpinitstandby -s myhost -P 2222
```

If you specify the same host name as the active WarehousePG coordinator, you must also specify a different port number with the `-P` option and a standby data directory with the `-S` option.

Remove the existing standby coordinator from your WarehousePG cluster configuration:

```
gpinitstandby -r
```

See Also

gpinitsystem, gpaddmirrors, gpactivatestandby

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7.7.2.17 gpinitsystem

Initializes a WarehousePG cluster using configuration parameters specified in the `gpinitsystem_config` file.

Synopsis

```
gpinitsystem -c <cluster_configuration_file>
            [-h <hostfile_gpinitsystem>]
            [-B <parallel_processes>]
            [-p <postgresql_conf_param_file>]
            [-s <standby_coordinator_host>
                [-P <standby_coordinator_port>]
                [-S <standby_coordinator_datadir> | --standby_datadir=<standby_coordinator_datadir>]]
            [-m <number> | --max_connections=number>]
            [-b <size> | --shared_buffers=<size>]
            [-n <locale> | --locale=<locale>] [--lc-collate=<locale>]
            [--lc-ctype=<locale>] [--lc-messages=<locale>]
            [--lc-monetary=<locale>] [--lc-numeric=<locale>]
            [--lc-time=<locale>] [-e <password> | --su_password=<password>]
            [--mirror-mode={group|spread}] [-a] [-q] [-l <logfile_directory>] [-D]
            [-I <input_configuration_file>]
            [-O <output_configuration_file>]

gpinitsystem -v | --version

gpinitsystem -? | --help
```

Description

The `gpinitsystem` utility creates a WarehousePG instance or writes an input configuration file using the values defined in a cluster configuration file and any command-line options that you provide. SeeInitialization Configuration File Format for more information about the configuration file. Before running this utility, make sure that you have installed the WarehousePG software on all the hosts in the array.

With the `<-O output_configuration_file>` option, `gpinitsystem` writes all provided configuration information to the specified output file. This file can be used with the `-I` option to create a new cluster or re-create a cluster from a backed up configuration. See Initialization Configuration File Format for more information.

In a WarehousePG DBMS, each database instance (the coordinator instance and all segment instances) must be initialized across all of the hosts in the system in such a way that they can all work together as a unified DBMS. The `gpinitsystem` utility takes care of initializing the WarehousePG coordinator and each segment instance, and configuring the system as a whole.

Before running `gpinitsystem`, you must set the `$GPHOME` environment variable to point to the location of your WarehousePG installation on the coordinator host and exchange SSH keys between all host addresses in the array using `gpssh-exkeys`.

This utility performs the following tasks:

- Verifies that the parameters in the configuration file are correct.
- Ensures that a connection can be established to each host address. If a host address cannot be reached, the utility will exit.
- Verifies the locale settings.
- Displays the configuration that will be used and prompts the user for confirmation.
- Initializes the coordinator instance.
- Initializes the standby coordinator instance (if specified).
- Initializes the primary segment instances.
- Initializes the mirror segment instances (if mirroring is configured).
- Configures the WarehousePG cluster and checks for errors.
- Starts the WarehousePG cluster.

> **Note** This utility uses secure shell (SSH) connections between systems to perform its tasks. In large WarehousePG deployments, cloud deployments, or deployments with a large number of segments per host, this utility may exceed the host's maximum threshold for unauthenticated connections. Consider updating the SSH `MaxStartups` and `MaxSessions` configuration parameters to increase this threshold. For more information about SSH configuration options, refer to the SSH documentation for your Linux distribution.

Options

-a Do not prompt the user for confirmation.

-B parallel_processes The number of segments to create in parallel. If not specified, the utility will start up to 4 parallel processes at a time.

-c cluster_configuration_file Required. The full path and filename of the configuration file, which contains all of the defined parameters to configure and initialize a new WarehousePG cluster. See Initialization Configuration File Format for a description of this file. You must provide either the `-c <cluster_configuration_file>` option or the `-I <input_configuration_file>` option to `gpinitsystem`.

-D Sets log output level to debug.

-h hostfile_gpinitsystem Optional. The full path and filename of a file that contains the host addresses of your segment hosts. If not specified on the command line, you can specify the host file using the `MACHINE_LIST_FILE` parameter in the gpinitsystem_config file.

-I input_configuration_file The full path and filename of an input configuration file, which defines the WarehousePG host systems, the coordinator instance and segment instances on the hosts, using the `QD_PRIMARY_ARRAY`, `PRIMARY_ARRAY`, and `MIRROR_ARRAY` parameters. The input configuration file is typically created by using `gpinitsystem` with the `-O output\_configuration\_file` option. Edit those parameters in order to initialize a new cluster or re-create a cluster from a backed up configuration. You must provide either the `-c <cluster_configuration_file>` option or the `-I <input_configuration_file>` option to `gpinitsystem`.

-n locale | --locale=locale Sets the default locale used by WarehousePG. If not specified, the default locale is `en_US.utf8`. A locale identifier consists of a language identifier and a region identifier, and optionally a character set encoding. For example, `sv_SE` is Swedish as spoken in Sweden, `en_US` is U.S. English, and `fr_CA` is French Canadian. If more than one character set can be useful for a locale, then the specifications look like this: `en_US.UTF-8` (locale specification and character set encoding). On most systems, the command `locale` will show the locale environment settings and `locale -a` will show a list of all available locales.

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--lc-collate=locale Similar to `--locale`, but sets the locale used for collation (sorting data). The sort order cannot be changed after WarehousePG is initialized, so it is important to choose a collation locale that is compatible with the character set encodings that you plan to use for your data. There is a special collation name of `C` or `POSIX` (byte-order sorting as opposed to dictionary-order sorting). The `C` collation can be used with any character encoding.

--lc-ctype=locale Similar to `--locale`, but sets the locale used for character classification (what character sequences are valid and how they are interpreted). This cannot be changed after WarehousePG is initialized, so it is important to choose a character classification locale that is compatible with the data you plan to store in WarehousePG.

--lc-messages=locale Similar to `--locale`, but sets the locale used for messages output by WarehousePG. The current version of WarehousePG does not support multiple locales for output messages (all messages are in English), so changing this setting will not have any effect.

--lc-monetary=locale Similar to `--locale`, but sets the locale used for formatting currency amounts.

--lc-numeric=locale Similar to `--locale`, but sets the locale used for formatting numbers.

--lc-time=locale Similar to `--locale`, but sets the locale used for formatting dates and times.

-l logfile_directory The directory to write the log file. Defaults to `~/gpAdminLogs`.

-m number | --max_connections=number Sets the maximum number of client connections allowed to the coordinator. The default is 250.

-O output_configuration_file Optional, used during new cluster initialization. This option writes the `cluster_configuration_file` information (used with -c) to the specified `output_configuration_file`. This file defines the WarehousePG members using the `QD_PRIMARY_ARRAY`, `PRIMARY_ARRAY`, and `MIRROR_ARRAY` parameters. Use this file as a template for the `-I input_configuration_file` option. See Examples for more information.

-p postgresql_conf_param_file Optional. The name of a file that contains `postgresql.conf` parameter settings that you want to set for WarehousePG. These settings will be used when the individual coordinator and segment instances are initialized. You can also set parameters after initialization using the `gpconfig` utility.

-q Run in quiet mode. Command output is not displayed on the screen, but is still written to the log file.

-b size | --shared_buffers=size Sets the amount of memory a WarehousePG server instance uses for shared memory buffers. You can specify sizing in kilobytes (kB), megabytes (MB) or gigabytes (GB). The default is 125MB.

-s standby_coordinator_host Optional. If you wish to configure a backup coordinator instance, specify the host name using this option. The WarehousePG software must already be installed and configured on this host.

-P standby_coordinator_port If you configure a standby coordinator instance with `-s`, specify its port number using this option. The default port is the same as the coordinator port. To run the standby and coordinator on the same host, you must use this option to specify a different port for the standby. The WarehousePG software must already be installed and configured on the standby host.

-S standby_coordinator_datadir | --standby_dir=standby_coordinator_datadir If you configure a standby coordinator host with `-s`, use this option to specify its data directory. If you configure a standby on the same host as the coordinator instance, the coordinator and standby must have separate data directories.

-e superuser_password | --su_password=superuser_password Use this option to specify the password to set for the WarehousePG superuser account (such as `gpadmin`). If this option is not specified, the default password `gparray` is assigned to the superuser account. You can use the `ALTER ROLE` command to change the password at a later time.

```
Recommended security best practices:

-   Do not use the default password option for production environments.
-   Change the password immediately after installation.
```

--mirror-mode={group|spread} Use this option to specify the placement of mirror segment instances on the segment hosts. The default, `group`, groups the mirror segments for all of a host's primary segments on a single alternate host. `spread` spreads mirror segments for the primary segments on a host across different hosts in the WarehousePG cluster. Spreading is only allowed if the number of hosts is greater than the number of segment instances per host. See Overview of Segment Mirroring for information about WarehousePG mirroring strategies.

-v | --version Print the `gpinitsystem` version and exit.

-? | --help Show help about `gpinitsystem` command line arguments, and exit.

Initialization Configuration File Format

`gpinitsystem` requires a cluster configuration file with the following parameters defined. An example initialization configuration file can be found in `$GPHOME/docs/cli_help/gpconfigs/gpinitsystem_config`.

To avoid port conflicts between WarehousePG and other applications, the WarehousePG port numbers should not be in the range specified by the operating system parameter `net.ipv4.ip_local_port_range`. For example, if `net.ipv4.ip_local_port_range = 10000 65535`, you could set WarehousePG base port numbers to these values.

```
PORT_BASE = 6000
MIRROR_PORT_BASE = 7000
```

MACHINE_LIST_FILE

Optional. Can be used in place of the `-h` option. This specifies the file that contains the list of the segment host address names that comprise the WarehousePG cluster. The coordinator host is assumed to be the host from which you are running the utility and should not be included in this file. If your segment hosts have multiple network interfaces, then this file would include all addresses for the host. Give the absolute path to the file.

SEG_PREFIX

Required. This specifies a prefix that will be used to name the data directories on the coordinator and segment instances. The naming convention for data directories in a WarehousePG cluster is SEG_PREFIXnumber where number starts with 0 for segment instances (the coordinator is always -1). So for example, if you choose the prefix `gpseg`, your coordinator instance data directory would be named `gpseg-1`, and the segment instances would be named `gpseg0`, `gpseg1`, `gpseg2`, `gpseg3`, and so on.

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PORT_BASE

Required. This specifies the base number by which primary segment port numbers are calculated. The first primary segment port on a host is set as `PORT_BASE`, and then incremented by one for each additional primary segment on that host. Valid values range from 1 through 65535.

DATA_DIRECTORY

Required. This specifies the data storage location(s) where the utility will create the primary segment data directories. The number of locations in the list dictate the number of primary segments that will get created per physical host (if multiple addresses for a host are listed in the host file, the number of segments will be spread evenly across the specified interface addresses). It is OK to list the same data storage area multiple times if you want your data directories created in the same location. The user who runs `gpinitsystem` (for example, the `gpadmin` user) must have permission to write to these directories. For example, this will create six primary segments per host:

```
declare -a DATA_DIRECTORY=(/data1/primary /data1/primary
/data1/primary /data2/primary /data2/primary /data2/primary)
```

COORDINATOR_HOSTNAME

Required. The host name of the coordinator instance. This host name must exactly match the configured host name of the machine (run the `hostname` command to determine the correct hostname).

COORDINATOR_DIRECTORY

Required. This specifies the location where the data directory will be created on the coordinator host. You must make sure that the user who runs `gpinitsystem` (for example, the `gpadmin` user) has permissions to write to this directory.

COORDINATOR_PORT

Required. The port number for the coordinator instance. This is the port number that users and client connections will use when accessing the WarehousePG cluster.

TRUSTED_SHELL

Required. The shell the `gpinitsystem` utility uses to run commands on remote hosts. Allowed values are `ssh`. You must set up your trusted host environment before running the `gpinitsystem` utility (you can use `gpssh-exkeys` to do this).

ENCODING

Required. The character set encoding to use. This character set must be compatible with the `--locale` settings used, especially `--lc-collate` and `--lc-ctype`. WarehousePG supports the same character sets as PostgreSQL.

DATABASE_NAME

Optional. The name of a WarehousePG database to create after the system is initialized. You can always create a database later using the `CREATE DATABASE` command or the `createdb` utility.

MIRROR_PORT_BASE

Optional. This specifies the base number by which mirror segment port numbers are calculated. The first mirror segment port on a host is set as `MIRROR_PORT_BASE`, and then incremented by one for each additional mirror segment on that host. Valid values range from 1 through 65535 and cannot conflict with the ports calculated by `PORT_BASE`.

MIRROR_DATA_DIRECTORY

Optional. This specifies the data storage location(s) where the utility will create the mirror segment data directories. There must be the same number of data directories declared for mirror segment instances as for primary segment instances (see the `DATA_DIRECTORY` parameter). The user who runs `gpinitsystem` (for example, the `gpadmin` user) must have permission to write to these directories. For example:

```
declare -a MIRROR_DATA_DIRECTORY=(/data1/mirror
/data1/mirror /data1/mirror /data2/mirror /data2/mirror
/data2/mirror)
```

QD_PRIMARY_ARRAY

PRIMARY_ARRAY

MIRROR_ARRAY

Required when using `input_configuration file` with `-I` option. These parameters specify the WarehousePG coordinator host, the primary segment, and the mirror segment hosts respectively. During new cluster initialization, use the `gpinitsystem -O output\_configuration\_file` to populate `QD_PRIMARY_ARRAY`, `PRIMARY_ARRAY`, `MIRROR_ARRAY`.

To initialize a new cluster or re-create a cluster from a backed up configuration, edit these values in the input configuration file used with the `gpinitsystem -I input\_configuration\_file` option. Use one of the following formats to specify the host information:

```
<hostname>~<address>~<port>~<data_directory>/<seg_prefix<segment_id>~<dbid>~<content_id>
```

or

```
<host>~<port>~<data_directory>/<seg_prefix<segment_id>~<dbid>~<content_id>
```

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The first format populates the `hostname` and `address` fields in the `gp_segment_configuration` catalog table with the hostname and address values provided in the input configuration file. The second format populates `hostname` and `address` fields with the same value, derived from host.

The WarehousePG coordinator always uses the value -1 for the segment ID and content ID. For example, seg_prefix<segment_id> and dbid values for `QD_PRIMARY_ARRAY` use `-1` to indicate the coordinator instance:

```
QD_PRIMARY_ARRAY=cdw~cdw~5432~/gpdata/coordinator/gpseg-1~1~-1
declare -a PRIMARY_ARRAY=(
sdw1~sdw1~40000~/gpdata/data1/gpseg0~2~0
sdw1~sdw1~40001~/gpdata/data2/gpseg1~3~1
sdw2~sdw2~40000~/gpdata/data1/gpseg2~4~2
sdw2~sdw2~40001~/gpdata/data2/gpseg3~5~3
)
declare -a MIRROR_ARRAY=(
sdw2~sdw2~50000~/gpdata/mirror1/gpseg0~6~0
sdw2~sdw2~50001~/gpdata/mirror2/gpseg1~7~1
sdw1~sdw1~50000~/gpdata/mirror1/gpseg2~8~2
sdw1~sdw1~50001~/gpdata/mirror2/gpseg3~9~3
)
```

To re-create a cluster using a known WarehousePG cluster configuration, you can edit the segment and content IDs to match the values of the system.

HEAP_CHECKSUM

Optional. This parameter specifies if checksums are enabled for heap data. When enabled, checksums are calculated for heap storage in all databases, enabling WarehousePG to detect corruption in the I/O system. This option is set when the system is initialized and cannot be changed later.

The `HEAP_CHECKSUM` option is on by default and turning it off is strongly discouraged. If you set this option to off, data corruption in storage can go undetected and make recovery much more difficult.

To determine if heap checksums are enabled in a WarehousePG cluster, you can query the `data_checksums` server configuration parameter with the `gpconfig` management utility:

```
$ gpconfig -s data_checksums
```

HBA_HOSTNAMES

Optional. This parameter controls whether `gpinitsystem` uses IP addresses or host names in the `pg_hba.conf` file when updating the file with addresses that can connect to WarehousePG. The default value is `0`, the utility uses IP addresses when updating the file. When Initializing WarehousePG, specify `HBA_HOSTNAMES=1` to have the utility use host names in the `pg_hba.conf` file.

For information about how WarehousePG resolves host names in the `pg_hba.conf` file, see Configuring Client Authentication.

Specifying Hosts using Hostnames or IP Addresses

When Initializing WarehousePG with `gpinitsystem`, you can specify segment hosts using either hostnames or IP addresses. For example, you can use hostnames or IP addresses in the file specified with the `-h` option.

- If you specify a hostname, the resolution of the hostname to an IP address should be done locally for security. For example, you should use entries in a local `/etc/hosts` file to map a hostname to an IP address. The resolution of a hostname to an IP address should not be performed by an external service such as a public DNS server. You must stop the WarehousePG cluster before you change the mapping of a hostname to a different IP address.
- If you specify an IP address, the address should not be changed after the initial configuration. When segment mirroring is enabled, replication from the primary to the mirror segment will fail if the IP address changes from the configured value. For this reason, you should use a hostname when Initializing WarehousePG unless you have a specific requirement to use IP addresses.

When initializing the WarehousePG cluster, `gpinitsystem` uses the initialization information to populate the gp_segment_configuration catalog table and adds hosts to the `pg_hba.conf` file. By default, the host IP address is added to the file. Specify the `gpinitsystem` configuration file parameter HBA_HOSTNAMES=1 to add hostnames to the file.

WarehousePG uses the `address` value of the `gp_segment_configuration` catalog table when looking up host systems for WarehousePG interconnect (internal) communication between the coordinator and segment instances and between segment instances, and for other internal communication.

Examples

Initialize a WarehousePG cluster by supplying a cluster configuration file and a segment host address file, and set up a spread mirroring (`--mirror-mode=spread`) configuration:

```
$ gpinitsystem -c gpinitsystem_config -h hostfile_gpinitsystem --mirror-mode=spread
```

Initialize a WarehousePG cluster and set the superuser remote password:

```
$ gpinitsystem -c gpinitsystem_config -h hostfile_gpinitsystem --su-password=mypassword
```

Initialize a WarehousePG cluster with an optional standby coordinator host:

```
$ gpinitsystem -c gpinitsystem_config -h hostfile_gpinitsystem -s host09
```

Initialize a WarehousePG cluster and write the provided configuration to an output file, for example `cluster_init.config`:

```
$ gpinitsystem -c gpinitsystem_config -h hostfile_gpinitsystem -O cluster_init.config
```

The output file uses the `QD_PRIMARY_ARRAY` and `PRIMARY_ARRAY` parameters to define coordinator and segment hosts:

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```
TRUSTED_SHELL=ssh
CHECK_POINT_SEGMENTS=8
ENCODING=UNICODE
SEG_PREFIX=gpseg
HEAP_CHECKSUM=on
HBA_HOSTNAMES=0
QD_PRIMARY_ARRAY=cdw~cdw.local~5433~/data/coordinator1/gpseg-1~1~-1
declare -a PRIMARY_ARRAY=(
cdw~cdw.local~6001~/data/primary1/gpseg0~2~0
)
declare -a MIRROR_ARRAY=(
cdw~cdw.local~7001~/data/mirror1/gpseg0~3~0
)
```

Initialize a WarehousePG using an input configuration file (a file that defines the WarehousePG cluster) using `QD_PRIMARY_ARRAY` and `PRIMARY_ARRAY` parameters:

```
$ gpinitsystem -I cluster_init.config
```

The following example uses a host system configured with multiple NICs. If host systems are configured with multiple NICs, you can initialize a WarehousePG cluster to use each NIC as a WarehousePG host system. You must ensure that the host systems are configured with sufficient resources to support all the segment instances being added to the host. Also, if high availability is enabled, you must ensure that the WarehousePG cluster configuration supports failover if a host system fails. For information about WarehousePG mirroring schemes, see ../../best_practices/ha.html#topic_ngz_qf4_tt.

For this simple coordinator and segment instance configuration, the host system `gp7c` is configured with two NICs `gp7c-1` and `gp7c-2`. In the configuration, the QD_PRIMARY_ARRAY parameter defines the coordinator segment using `gp7c-1`. The PRIMARY_ARRAY and MIRROR_ARRAY parameters use `gp7c-2` to define a primary and mirror segment instance.

```
QD_PRIMARY_ARRAY=gp7c~gp7c-1~5432~/data/coordinator/gpseg-1~1~-1
declare -a PRIMARY_ARRAY=(
gp7c~gp7c-2~40000~/data/data1/gpseg0~2~0
gp7s~gp7s~40000~/data/data1/gpseg1~3~1
)
declare -a MIRROR_ARRAY=(
gp7s~gp7s~50000~/data/mirror1/gpseg0~4~0
gp7c~gp7c-2~50000~/data/mirror1/gpseg1~5~1
)
```

See Also

gpssh-exkeys, gpdeletesystem, Initializing WarehousePG.

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7.7.2.18 gpload

Runs a load job as defined in a YAML formatted control file.

Synopsis

```
gpload -f <control_file> [-l <log_file>] [-h <hostname>] [-p <port>]
   [-U <username>] [-d <database>] [-W] [--gpfdist_timeout <seconds>]
   [--no_auto_trans] [--max_retries <retry_times>] [[-v | -V] [-q]] [-D]

gpload -?

gpload --version
```

Requirements

The client machine where `gpload` is run must have the following:

- The gpfdist parallel file distribution program installed and in your `$PATH`. This program is located in `$GPHOME/bin` of your WarehousePG server installation.
- Network access to and from all hosts in your WarehousePG cluster (coordinator and segments).
- Network access to and from the hosts where the data to be loaded resides (ETL servers).

Description

`gpload` is a data loading utility that acts as an interface to the WarehousePG external table parallel loading feature. Using a load specification defined in a YAML formatted control file, `gpload` runs a load by invoking the WarehousePG parallel file server (gpfdist), creating an external table definition based on the source data defined, and running an `INSERT`, `UPDATE` or `MERGE` operation to load the source data into the target table in the database.

> **Note** `gpfdist` is compatible only with the WarehousePG major version in which it is shipped. For example, a `gpfdist` utility that is installed with WarehousePG 6.x cannot be used with WarehousePG 7.x.

> **Note** `MERGE` and `UPDATE` operations are not supported if the target table column name is a reserved keyword, has capital letters, or includes any character that requires quotes (" ") to identify the column.

The operation, including any SQL commands specified in the `SQL` collection of the YAML control file (see Control File Format), are performed as a single transaction to prevent inconsistent data when performing multiple, simultaneous load operations on a target table.

Options

-f control_file Required. A YAML file that contains the load specification details. See Control File Format.

--gpfdist_timeout seconds Sets the timeout for the `gpfdist` parallel file distribution program to send a response. Enter a value from `0` to `30` seconds (entering " `0` " to deactivates timeouts). Note that you might need to increase this value when operating on high-traffic networks.

-l log_file Specifies where to write the log file. Defaults to `~/gpAdminLogs/gpload_YYYYMMDD`. For more information about the log file, see Log File Format.

--no_auto_trans Specify `--no_auto_trans` to deactivate processing the load operation as a single transaction if you are performing a single load operation on the target table.

By default, `gpload` processes each load operation as a single transaction to prevent inconsistent data when performing multiple, simultaneous operations on a target table.

-q (no screen output) Run in quiet mode. Command output is not displayed on the screen, but is still written to the log file.

-D (debug mode) Check for error conditions, but do not run the load.

-v (verbose mode) Show verbose output of the load steps as they are run.

-V (very verbose mode) Shows very verbose output.

-? (show help) Show help, then exit.

--version Show the version of this utility, then exit.

Connection Options

-d database The database to load into. If not specified, reads from the load control file, the environment variable `$PGDATABASE` or defaults to the current system user name.

-h hostname Specifies the host name of the machine on which the WarehousePG coordinator database server is running. If not specified, reads from the load control file, the environment variable `$PGHOST` or defaults to `localhost`.

-p port Specifies the TCP port on which the WarehousePG coordinator database server is listening for connections. If not specified, reads from the load control file, the environment variable `$PGPORT` or defaults to 5432.

--max_retries retry_times Specifies the maximum number of times `gpload` attempts to connect to WarehousePG after a connection timeout. The default value is `0`, do not attempt to connect after a connection timeout. A negative integer, such as `-1`, specifies an unlimited number of attempts.

-U username The database role name to connect as. If not specified, reads from the load control file, the environment variable `$PGUSER` or defaults to the current system user name.

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-W (force password prompt) Force a password prompt. If not specified, reads the password from the environment variable `$PGPASSWORD` or from a password file specified by `$PGPASSFILE` or in `~/.pgpass`. If these are not set, then `gpload` will prompt for a password even if `-W` is not supplied.

Control File Format

The `gpload` control file uses the YAML 1.1 document format and then implements its own schema for defining the various steps of a WarehousePG load operation. The control file must be a valid YAML document.

The `gpload` program processes the control file document in order and uses indentation (spaces) to determine the document hierarchy and the relationships of the sections to one another. The use of white space is significant. White space should not be used simply for formatting purposes, and tabs should not be used at all.

The basic structure of a load control file is:

```
---
VERSION: 1.0.0.1
DATABASE: <db_name>
USER: <db_username>
HOST: <coordinator_hostname>
PORT: <coordinator_port>
GPLOAD:
   INPUT:
    - SOURCE:
         LOCAL_HOSTNAME:
           - <hostname_or_ip>
         PORT: <http_port>
       | PORT_RANGE: [<start_port_range>, <end_port_range>]
         FILE:
           - </path/to/input_file>
         SSL: true | false
         CERTIFICATES_PATH: </path/to/certificates>
    - FULLY_QUALIFIED_DOMAIN_NAME: true | false
    - COLUMNS:
           - <field_name>: <data_type>
    - TRANSFORM: '<transformation>'
    - TRANSFORM_CONFIG: '<configuration-file-path>'
    - MAX_LINE_LENGTH: <integer>
    - FORMAT: text | csv
    - DELIMITER: '<delimiter_character>'
    - ESCAPE: '<escape_character>' | 'OFF'
    - NEWLINE: 'LF' | 'CR' | 'CRLF'
    - NULL_AS: '<null_string>'
    - FILL_MISSING_FIELDS: true | false
    - FORCE_NOT_NULL: true | false
    - QUOTE: '<csv_quote_character>'
    - HEADER: true | false
    - ENCODING: <database_encoding>
    - ERROR_LIMIT: <integer>
    - LOG_ERRORS: true | false
   EXTERNAL:
      - SCHEMA: <schema> | '%'
   OUTPUT:
    - TABLE: <schema.table_name>
    - MODE: insert | update | merge
    - MATCH_COLUMNS:
           - <target_column_name>
    - UPDATE_COLUMNS:
           - <target_column_name>
    - UPDATE_CONDITION: '<boolean_condition>'
    - MAPPING:
             <target_column_name>: <source_column_name> | '<expression>'
   PRELOAD:
    - TRUNCATE: true | false
    - REUSE_TABLES: true | false
    - STAGING_TABLE: <external_table_name>
    - FAST_MATCH: true | false
   SQL:
    - BEFORE: "<sql_command>"
    - AFTER: "<sql_command>"
```

VERSION Optional. The version of the `gpload` control file schema. The current version is 1.0.0.1.

DATABASE Optional. Specifies which database in the WarehousePG cluster to connect to. If not specified, defaults to `$PGDATABASE` if set or the current system user name. You can also specify the database on the command line using the `-d` option.

USER Optional. Specifies which database role to use to connect. If not specified, defaults to the current user or `$PGUSER` if set. You can also specify the database role on the command line using the `-U` option.

If the user running `gpload` is not a WarehousePG superuser, then the appropriate rights must be granted to the user for the load to be processed. See the *WarehousePG Reference Guide* for more information.

HOST Optional. Specifies WarehousePG coordinator host name. If not specified, defaults to localhost or `$PGHOST` if set. You can also specify the coordinator host name on the command line using the `-h` option.

PORT Optional. Specifies WarehousePG coordinator port. If not specified, defaults to 5432 or `$PGPORT` if set. You can also specify the coordinator port on the command line using the `-p` option.

GPLOAD Required. Begins the load specification section. A `GPLOAD` specification must have an `INPUT` and an `OUTPUT` section defined.

```
INPUT
Required. Defines the location and the format of the input data to be loaded. `gpload` will start one or more instances of the [gpfdist](gpfdist.html) file
distribution program on the current host and create the required external table definition\(s\) in WarehousePG that point to the source data. Note that the host
```

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from which you run `gpload` must be accessible over the network by all WarehousePG hosts \(coordinator and segments\).

SOURCE
Required. The `SOURCE` block of an `INPUT` specification defines the location of a source file. An `INPUT` section can have more than one `SOURCE` block defined. Each `SOURCE` block defined corresponds to one instance of the [gpfdist](gpfdist.html) file distribution program that will be started on the local machine. Each `SOURCE` block defined must have a `FILE` specification.

For more information about using the `gpfdist` parallel file server and single and multiple `gpfdist` instances, see [Loading and Unloading Data](../../admin_guide/load/topics/g-loading-and-unloading-data.html).

LOCAL_HOSTNAME
Optional. Specifies the host name or IP address of the local machine on which `gpload` is running. If this machine is configured with multiple network interface cards \(NICs\), you can specify the host name or IP of each individual NIC to allow network traffic to use all NICs simultaneously. The default is to use the local machine's primary host name or IP only.

PORT
Optional. Specifies the specific port number that the [gpfdist](gpfdist.html) file distribution program should use. You can also supply a `PORT_RANGE` to select an available port from the specified range. If both `PORT` and `PORT_RANGE` are defined, then `PORT` takes precedence. If neither `PORT` or `PORT_RANGE` are defined, the default is to select an available port between 8000 and 9000.

If multiple host names are declared in `LOCAL_HOSTNAME`, this port number is used for all hosts. This configuration is desired if you want to use all NICs to load the same file or set of files in a given directory location.

PORT_RANGE
Optional. Can be used instead of `PORT` to supply a range of port numbers from which `gpload` can choose an available port for this instance of the [gpfdist](gpfdist.html) file distribution program.

FILE
Required. Specifies the location of a file, named pipe, or directory location on the local file system that contains data to be loaded. You can declare more than one file so long as the data is of the same format in all files specified.

If the files are compressed using `gzip` or `bzip2` \(have a `.gz` or `.bz2` file extension\), the files will be uncompressed automatically \(provided that `gunzip` or `bunzip2` is in your path\).

When specifying which source files to load, you can use the wildcard character \(`*`\) or other C-style pattern matching to denote multiple files. The files specified are assumed to be relative to the current directory from which `gpload` is run \(or you can declare an absolute path\).

SSL
Optional. Specifies usage of SSL encryption. If `SSL` is set to true, `gpload` starts the `gpfdist` server with the `--ssl` option and uses the `gpfdists://` protocol.

CERTIFICATES_PATH
Required when SSL is `true`; cannot be specified when SSL is `false` or unspecified. The location specified in `CERTIFICATES_PATH` must contain the following files:

- The server certificate file, `server.crt`
- The server private key file, `server.key`
- The trusted certificate authorities, `root.crt`

The root directory \(`/`\) cannot be specified as `CERTIFICATES_PATH`.

FULLY_QUALIFIED_DOMAIN_NAME
Optional. Specifies whether `gpload` resolve hostnames to the fully qualified domain name \(FQDN\) or the local hostname. If the value is set to `true`, names are resolved to the FQDN. If the value is set to `false`, resolution is to the local hostname. The default is `false`.

A fully qualified domain name might be required in some situations. For example, if the WarehousePG cluster is in a different domain than an ETL application that is being accessed by `gpload`.

COLUMNS
Optional. Specifies the schema of the source data file\(s\) in the format of `field\_name:data\_type`. The `DELIMITER` character in the source file is what separates two data value fields \(columns\). A row is determined by a line feed character \(`0x0a`\).

If the input `COLUMNS` are not specified, then the schema of the output `TABLE` is implied, meaning that the source data must have the same column order, number of columns, and data format as the target table.

The default source-to-target mapping is based on a match of column names as defined in this section and the column names in the target `TABLE`. This default mapping can be overridden using the `MAPPING` section.

TRANSFORM
Optional. Specifies the name of the input transformation passed to `gpload`. For information about XML transformations, see "Loading and Unloading Data" in the *WarehousePG Administrator Guide*.

TRANSFORM_CONFIG
Required when `TRANSFORM` is specified. Specifies the location of the transformation configuration file that is specified in the `TRANSFORM` parameter, above.

MAX_LINE_LENGTH
Optional. Sets the maximum allowed data row length in bytes. Default is 32768. Should be used when user data includes very wide rows (or when `line too long` error message occurs). Should not be used otherwise as it increases resource allocation. Valid range is 32K to 256MB. The upper limit is 1MB on Windows systems.

FORMAT
Optional. Specifies the format of the source data file\(s\) - either plain text \(`TEXT`\) or comma separated values \(`CSV`\) format. Defaults to `TEXT` if not specified. For more information about the format of the source data, see [Loading and Unloading Data](../../admin_guide/load/topics/g-loading-and-unloading-data.html).

DELIMITER
Optional. Specifies a single ASCII character that separates columns within each row \(line\) of data. The default is a tab character in TEXT mode, a comma in CSV mode. You can also specify a non- printable ASCII character or a non-printable unicode character, for example: `"\x1B"` or `"\u001B"`. The escape string syntax, `E'<character-code>'`, is also supported for non-printable characters. The ASCII or unicode character must be enclosed in single quotes. For example: `E'\x1B'` or `E'\u001B'`.

ESCAPE
Specifies the single character that is used for C escape sequences \(such as `\n`, `\t`, `\100`, and so on\) and for escaping data characters that might otherwise be taken as row or column delimiters. Make sure to choose an escape character that is not used anywhere in your actual column data. The default escape character

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```
is a \\ \(backslash\) for text-formatted files and a `"` \(double quote\) for csv-formatted files, however it is possible to specify another character to represent an escape. It is also possible to deactivate escaping in text-formatted files by specifying the value `'OFF'` as the escape value. This is very useful for data such as text-formatted web log data that has many embedded backslashes that are not intended to be escapes.

NEWLINE
Specifies the type of newline used in your data files, one of:

-   LF \(Line feed, 0x0A\)
-   CR \(Carriage return, 0x0D\)
-   CRLF \(Carriage return plus line feed, 0x0D 0x0A\).

If not specified, WarehousePG detects the newline type by examining the first row of data that it receives, and uses the first newline type that it encounters.

NULL\_AS
Optional. Specifies the string that represents a null value. The default is `\N` \(backslash-N\) in `TEXT` mode, and an empty value with no quotations in `CSV` mode. You might prefer an empty string even in `TEXT` mode for cases where you do not want to distinguish nulls from empty strings. Any source data item that matches this string will be considered a null value.

FILL\_MISSING\_FIELDS
Optional. The default value is `false`. When reading a row of data that has missing trailing field values \(the row of data has missing data fields at the end of a line or row\), WarehousePG returns an error.

If the value is `true`, when reading a row of data that has missing trailing field values, the values are set to `NULL`. Blank rows, fields with a `NOT NULL` constraint, and trailing delimiters on a line will still report an error.

See the `FILL MISSING FIELDS` clause of the [CREATE EXTERNAL TABLE](../../ref_guide/sql_commands/CREATE_EXTERNAL_TABLE.html) command.

FORCE\_NOT\_NULL
Optional. In CSV mode, processes each specified column as though it were quoted and hence not a NULL value. For the default null string in CSV mode \(nothing between two delimiters\), this causes missing values to be evaluated as zero-length strings.

QUOTE
Required when `FORMAT` is `CSV`. Specifies the quotation character for `CSV` mode. The default is double-quote \(`"`\).

HEADER
Optional. Specifies that the first line in the data file\(s\) is a header row \(contains the names of the columns\) and should not be included as data to be loaded. If using multiple data source files, all files must have a header row. The default is to assume that the input files do not have a header row.

ENCODING
Optional. Character set encoding of the source data. Specify a string constant \(such as `'SQL_ASCII'`\), an integer encoding number, or `'DEFAULT'` to use the default client encoding. If not specified, the default client encoding is used. For information about supported character sets, see the *WarehousePG Reference Guide*.

> **Note** If you *change* the `ENCODING` value in an existing `gpload` control file, you must manually drop any external tables that were creating using the previous `ENCODING` configuration. `gpload` does not drop and recreate external tables to use the new `ENCODING` if `REUSE_TABLES` is set to `true`.

ERROR\_LIMIT
Optional. Enables single row error isolation mode for this load operation. When enabled, input rows that have format errors will be discarded provided that the error limit count is not reached on any WarehousePG segment instance during input processing. If the error limit is not reached, all good rows will be loaded and any error rows will either be discarded or captured as part of error log information. The default is to cancel the load operation on the first error encountered. Note that single row error isolation only applies to data rows with format errors; for example, extra or missing attributes, attributes of a wrong data type, or invalid client encoding sequences. Constraint errors, such as primary key violations, will still cause the load operation to be cancelled if encountered. For information about handling load errors, see [Loading and Unloading Data](../../admin_guide/load/topics/g-loading-and-unloading-data.html).

LOG\_ERRORS
Optional when `ERROR_LIMIT` is declared. Value is either `true` or `false`. The default value is `false`. If the value is `true`, rows with formatting errors are logged internally when running in single row error isolation mode. You can examine formatting errors with the WarehousePG built-in SQL function `gp_read_error_log('<table_name>')`. If formatting errors are detected when loading data, `gpload` generates a warning message with the name of the table that contains the error information similar to this message.

```
<timestamp>|WARN|1 bad row, please use GPDB built-in function gp_read_error_log('table-name')
   to access the detailed error row
```

If `LOG_ERRORS: true` is specified, `REUSE_TABLES: true` must be specified to retain the formatting errors in WarehousePG error logs. If `REUSE_TABLES: true` is not specified, the error information is deleted after the `gpload` operation. Only summary information about formatting errors is returned. You can delete the formatting errors from the error logs with the WarehousePG function `gp_truncate_error_log()`.

> **Note** When `gpfdist` reads data and encounters a data formatting error, the error message includes a row number indicating the location of the formatting error. `gpfdist` attempts to capture the row that contains the error. However, `gpfdist` might not capture the exact row for some formatting errors.

For more information about handling load errors, see "Loading and Unloading Data" in the *WarehousePG Administrator Guide*. For information about the `gp_read_error_log()` function, see the [CREATE EXTERNAL TABLE](../../ref_guide/sql_commands/CREATE_EXTERNAL_TABLE.html) command.

EXTERNAL
Optional. Defines the schema of the external table database objects created by `gpload`.

The default is to use the WarehousePG `search_path`.

SCHEMA
```

Required when `EXTERNAL` is declared. The name of the schema of the external table. If the schema does not exist, an error is returned.

If `%` (percent character) is specified, the schema of the table name specified by `TABLE` in the `OUTPUT` section is used. If the table name does not specify a schema, the default schema is used.

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```
OUTPUT
Required. Defines the target table and final data column values that are to be loaded into the database.

TABLE
Required. The name of the target table to load into.

MODE
Optional. Defaults to `INSERT` if not specified. There are three available load modes:

INSERT - Loads data into the target table using the following method:

```
INSERT INTO <target_table> SELECT * FROM <input_data>;
```

UPDATE - Updates the `UPDATE_COLUMNS` of the target table where the rows have `MATCH_COLUMNS` attribute values equal to those of the input data, and the optional `UPDATE_CONDITION` is true. `UPDATE` is not supported if the target table column name is a reserved keyword, has capital letters, or includes any character that requires quotes \(" "\) to identify the column.

MERGE - Inserts new rows and updates the `UPDATE_COLUMNS` of existing rows where attribute values are equal to those of the input data, and the optional `MATCH_COLUMNS` is true. New rows are identified when the `MATCH_COLUMNS` value in the source data does not have a corresponding value in the existing data of the target table. In those cases, the **entire row** from the source file is inserted, not only the `MATCH` and `UPDATE` columns. If there are multiple new `MATCH_COLUMNS` values that are the same, only one new row for that value will be inserted. Use `UPDATE_CONDITION` to filter out the rows to discard. `MERGE` is not supported if the target table column name is a reserved keyword, has capital letters, or includes any character that requires quotes \(" "\) to identify the column.

MATCH_COLUMNS
Required if `MODE` is `UPDATE` or `MERGE`. Specifies the column\(s\) to use as the join condition for the update. The attribute value in the specified target column\(s\) must be equal to that of the corresponding source data column\(s\) in order for the row to be updated in the target table.

UPDATE_COLUMNS
Required if `MODE` is `UPDATE` or `MERGE`. Specifies the column\(s\) to update for the rows that meet the `MATCH_COLUMNS` criteria and the optional `UPDATE_CONDITION`.

UPDATE_CONDITION
Optional. Specifies a Boolean condition \(similar to what you would declare in a `WHERE` clause\) that must be met in order for a row in the target table to be updated.

MAPPING
Optional. If a mapping is specified, it overrides the default source-to-target column mapping. The default source-to-target mapping is based on a match of column names as defined in the source `COLUMNS` section and the column names of the target `TABLE`. A mapping is specified as either:

`<target_column_name>: <source_column_name>`

or

`<target_column_name>: '<expression>'`

Where <expression\> is any expression that you would specify in the `SELECT` list of a query, such as a constant value, a column reference, an operator invocation, a function call, and so on.
```

PRELOAD Optional. Specifies operations to run prior to the load operation. Right now the only preload operation is `TRUNCATE`.

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```
TRUNCATE
Optional. If set to true, `gpload` will remove all rows in the target table prior to loading it. Default is false.

REUSE\_TABLES
Optional. If set to true, `gpload` will not drop the external table objects and staging table objects it creates. These objects will be reused for future load operations that use the same load specifications. This improves performance of trickle loads \(ongoing small loads to the same target table\).

If `LOG_ERRORS: true` is specified, `REUSE_TABLES: true` must be specified to retain the formatting errors in WarehousePG error logs. If `REUSE_TABLES: true` is not specified, formatting error information is deleted after the `gpload` operation.

If the <external\_table\_name\> exists, the utility uses the existing table. The utility returns an error if the table schema does not match the `OUTPUT` table schema.

STAGING\_TABLE
Optional. Specify the name of the temporary external table that is created during a `gpload` operation. The external table is used by `gpfdist`. `REUSE_TABLES: true` must also specified. If `REUSE_TABLES` is false or not specified, `STAGING_TABLE` is ignored. By default, `gpload` creates a temporary external table with a randomly generated name.

If external\_table\_name contains a period \(.\), `gpload` returns an error. If the table exists, the utility uses the table. The utility returns an error if the existing table schema does not match the `OUTPUT` table schema.

The utility uses the value of [SCHEMA](#cfschema) in the `EXTERNAL` section as the schema for <external\_table\_name\>. If the `SCHEMA` value is `%`, the schema for <external\_table\_name\> is the same as the schema of the target table, the schema of [TABLE](#cftable) in the `OUTPUT` section.

If `SCHEMA` is not set, the utility searches for the table \(using the schemas in the database `search_path`\). If the table is not found, external\_table\_name is created in the default `PUBLIC` schema.

`gpload` creates the staging table using the distribution key\(s\) of the target table as the distribution key\(s\) for the staging table. If the target table was created `DISTRIBUTED RANDOMLY`, `gpload` uses `MATCH_COLUMNS` as the staging table's distribution key\(s\).

FAST\_MATCH
Optional. If set to true, `gpload` only searches the database for matching external table objects when reusing external tables. The utility does not check the external table column names and column types in the catalog table `pg_attribute` to ensure that the table can be used for a `gpload` operation. Set the value to true to improve `gpload` performance when reusing external table objects and the database catalog table `pg_attribute` contains a large number of rows. The utility returns an error and quits if the column definitions are not compatible.

The default value is false, the utility checks the external table definition column names and column types.

`REUSE_TABLES: true` must also specified. If `REUSE_TABLES` is false or not specified and `FAST_MATCH: true` is specified, `gpload` returns a warning message.
```

SQL Optional. Defines SQL commands to run before and/or after the load operation. You can specify multiple `BEFORE` and/or `AFTER` commands. List commands in the order of desired execution.

```
BEFORE
Optional. An SQL command to run before the load operation starts. Enclose commands in quotes.

AFTER
Optional. An SQL command to run after the load operation completes. Enclose commands in quotes.
```

Log File Format

Log files output by `gpload` have the following format:

```
<timestamp>|<level>|<message>
```

Where <timestamp> takes the form: `YYYY-MM-DD HH:MM:SS`, level is one of `DEBUG`, `LOG`, `INFO`, `ERROR`, and message is a normal text message.

Some `INFO` messages that may be of interest in the log files are (where # corresponds to the actual number of seconds, units of data, or failed rows):

```
INFO|running time: <#.##> seconds
INFO|transferred <#.#> kB of <#.#> kB.
INFO|gpload succeeded
INFO|gpload succeeded with warnings
INFO|gpload failed
INFO|1 bad row
INFO|<#> bad rows
```

Notes

If your database object names were created using a double-quoted identifier (delimited identifier), you must specify the delimited name within single quotes in the `gpload` control file. For example, if you create a table as follows:

```
CREATE TABLE "MyTable" ("MyColumn" text);
```

Your YAML-formatted `gpload` control file would refer to the above table and column names as follows:

```
- COLUMNS:
   - '"MyColumn"': text
OUTPUT:
   - TABLE: public.'"MyTable"'
```

If the YAML control file contains the unsupported `ERROR_TABLE` element, `gpload` logs a warning stating that `ERROR_TABLE` is not supported, and load errors are handled as if the `LOG_ERRORS` and `REUSE_TABLE` elements were set to `true`. Rows with formatting errors are logged internally when running in single row error isolation mode.

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Examples

Run a load job as defined in `my_load.yml`:

```
gpload -f my_load.yml
```

Example load control file:

```
---
VERSION: 1.0.0.1
DATABASE: ops
USER: gpadmin
HOST: cdw-1
PORT: 5432
GPLOAD:
   INPUT:
    - SOURCE:
         LOCAL_HOSTNAME:
           - etl1-1
           - etl1-2
           - etl1-3
           - etl1-4
         PORT: 8081
         FILE:
           - /var/load/data/*
    - COLUMNS:
           - name: text
           - amount: float4
           - category: text
           - descr: text
           - date: date
    - FORMAT: text
    - DELIMITER: '|'
    - ERROR_LIMIT: 25
    - LOG_ERRORS: true
   OUTPUT:
    - TABLE: payables.expenses
    - MODE: INSERT
   PRELOAD:
    - REUSE_TABLES: true
   SQL:
   - BEFORE: "INSERT INTO audit VALUES('start', current_timestamp)"
   - AFTER: "INSERT INTO audit VALUES('end', current_timestamp)"
```

See Also

gpfdist, CREATE EXTERNAL TABLE

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7.7.2.19 gplogfilter

Searches through WarehousePG log files for specified entries.

Synopsis

```
gplogfilter [<timestamp_options>] [<pattern_options>]
     [<output_options>] [<input_options>] [<input_file>]

gplogfilter --help

gplogfilter --version
```

Description

The `gplogfilter` utility can be used to search through a WarehousePG log file for entries matching the specified criteria. If an input file is not supplied, then `gplogfilter` will use the `$COORDINATOR_DATA_DIRECTORY` environment variable to locate the WarehousePG coordinator log file in the standard logging location. To read from standard input, use a dash (`-`) as the input file name. Input files may be compressed using `gzip` . In an input file, a log entry is identified by its timestamp in `YYYY-MM-DD [hh:mm[:ss]]` format.

You can also use `gplogfilter` to search through all segment log files at once by running it through the gpssh utility. For example, to display the last three lines of each segment log file:

```
gpssh -f seg_host_file
=> source /usr/edb/whpg7/greenplum_path.sh
=> gplogfilter -n 3 /gpdata/*/log/gpdb*.csv
```

By default, the output of `gplogfilter` is sent to standard output. Use the `-o` option to send the output to a file or a directory. If you supply an output file name ending in `.gz` , the output file will be compressed by default using maximum compression. If the output destination is a directory, the output file is given the same name as the input file.

Options

Timestamp Options

`-b datetime | --begin=datetime` Specifies a starting date and time to begin searching for log entries in the format of `YYYY-MM-DD [hh:mm[:ss]]` .

If a time is specified, the date and time must be enclosed in either single or double quotes. This example encloses the date and time in single quotes:

```
gplogfilter -b '2013-05-23 14:33'
```

`-e datetime | --end=datetime` Specifies an ending date and time to stop searching for log entries in the format of `YYYY-MM-DD [hh:mm[:ss]]` .

If a time is specified, the date and time must be enclosed in either single or double quotes. This example encloses the date and time in single quotes:

```
gplogfilter -e '2013-05-23 14:33'
```

`-d<time> | --duration=<time>` Specifies a time duration to search for log entries in the format of `[hh][:mm[:ss]]` . If used without either the `-b` or `-e` option, will use the current time as a basis.

Pattern Matching Options

`-c i \[gnore] | r \[espect] | --case=i \[gnore] | r \[espect]` Matching of alphabetic characters is case sensitive by default unless proceeded by the `--case=ignore` option.

`-C 'string' | --columns='string'` Selects specific columns from the log file. Specify the desired columns as a comma-delimited string of column numbers beginning with 1, where the second column from left is 2, the third is 3, and so on. See "Viewing the Database Server Log Files" in the *WarehousePG Administrator Guide* for details about the log file format and for a list of the available columns and their associated number.

`-f 'string' | --find='string'` Finds the log entries containing the specified string.

`-F 'string' | --nofind='string'` Rejects the log entries containing the specified string.

`-m regex | --match=regex` Finds log entries that match the specified Python regular expression. See https://docs.python.org/library/re.html for Python regular expression syntax.

`-M regex | --nomatch=regex` Rejects log entries that match the specified Python regular expression. See https://docs.python.org/library/re.html for Python regular expression syntax.

`-t | --trouble` Finds only the log entries that have `ERROR:` , `FATAL:` , or `PANIC:` in the first line.

Output Options

`-n <integer> | --tail=<integer>` Limits the output to the last <integer> of qualifying log entries found.

`-s <offset> </offset>\[limit] | --slice=<offset> </offset>\[limit]` From the list of qualifying log entries, returns the <limit> number of entries starting at the <offset> entry number, where an <offset> of zero (`0`) denotes the first entry in the result set and an <offset> of any number greater than zero counts back from the end of the result set.

`-o <output_file> | --out=<output_file>` Writes the output to the specified file or directory location instead of `STDOUT` .

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`-z 0-9 | --zip=0-9` Compresses the output file to the specified compression level using `gzip`, where `0` is no compression and `9` is maximum compression. If you supply an output file name ending in `.gz`, the output file will be compressed by default using maximum compression.

`-a | --append` If the output file already exists, appends to the file instead of overwriting it.

Input Options

`input_file` The name of the input log file(s) to search through. If an input file is not supplied, `gplogfilter` will use the `$COORDINATOR_DATA_DIRECTORY` environment variable to locate the WarehousePG coordinator log file. To read from standard input, use a dash (`-`) as the input file name.

`-u | --unzip` Uncompress the input file using `gunzip`. If the input file name ends in `.gz`, it will be uncompressed by default.

`--help` Displays the online help.

`--version` Displays the version of this utility.

Examples

Display the last three error messages in the coordinator log file:

```
gplogfilter -t -n 3
```

Display all log messages in the coordinator log file timestamped in the last 10 minutes:

```
gplogfilter -d :10
```

Display log messages in the coordinator log file containing the string `|con6 cmd11|`:

```
gplogfilter -f '|con6 cmd11|'
```

Using gpssh, run `gplogfilter` on the segment hosts and search for log messages in the segment log files containing the string `con6` and save output to a file.

```
gpssh -f seg_hosts_file -e 'source
/usr/edb/whpg7/greenplum_path.sh ; gplogfilter -f
con6 /gpdata/*/log/gpdb*.csv' > seglog.out
```

See Also

gpssh, gpsync

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7.7.2.20 gpmemreport

Interprets the output created by the gpmemwatcher utility and generates output files in a readable format.

Synopsis

```
gpmemreport [<GZIP_FILE>] [[-s <START>] | [--start= <START>]] [[-e <END>] | [--end= <END>]]

gpmemreport --version

gpmemreport -h | --help
```

Description

The `gpmemreport` utility helps interpret the output file created by the gpmemwatcher utility.

When running `gpmemreport` against the `.gz` files generated by `gpmemwatcher`, it generates a series of files, where each file corresponds to a 60 second period of data collected by `gpmemwatcher` converted into a readable format.

Options

-s | --start start_time Indicates the start of the reporting period. Timestamp format must be `'%Y-%m-%d %H:%M:%S'`.

-e | --end end_time Indicates the end of the reporting period. Timestamp format must be `'%Y-%m-%d %H:%M:%S'`.

--version Displays the version of this utility.

-h | --help Displays the online help.

Examples

Example 1: Extract all the files generated by `gpmemwatcher` for the WarehousePG coordinator

Locate the output `.gz` file from `gpmemwatcher` and run `gpmemreport` against it:

```
$ gpmemreport cdw.ps.out.gz
>>>21:11:19:15:37:18<<<

>>>21:11:19:15:38:18<<<

>>>21:11:19:15:39:18<<<
```

Check that the generated files are listed under the current directory:

```
$ ls -thrl
-rw-rw-r--. 1 gpadmin gpadmin 1.2K Nov 19 15:50 20211119-153718
-rw-rw-r--. 1 gpadmin gpadmin 1.2K Nov 19 15:50 20211119-153818
-rw-rw-r--. 1 gpadmin gpadmin 1.2K Nov 19 15:50 20211119-153918
```

Example 2: Extract the files generated by `gpmemwatcher` for the WarehousePG coordinator starting after a certain timestamp

Locate the output `.gz` file from `gpmemwatcher` and run `gpmemreport` against it, indicating the start time as `2021-11-19 15:38:00`:

```
$ gpmemreport cdw.ps.out.gz --start='2021-11-19 15:38:00'
>>>21:11:19:15:37:18<<<

>>>21:11:19:15:38:18<<<

>>>21:11:19:15:39:18<<<
```

Check under the current directory that only the selected timestamp files are listed:

```
$ ls -thrl
-rw-rw-r--. 1 gpadmin gpadmin 1.2K Nov 19 15:50 20211119-153818
-rw-rw-r--. 1 gpadmin gpadmin 1.2K Nov 19 15:50 20211119-153918
```

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See Also

gpmemwatcher

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7.7.2.21 gpmemwatcher

Tracks the memory usage of each process in a WarehousePG cluster.

Synopsis

```
gpmemwatcher [-f | --host_file <hostfile>]

gpmemwatcher --stop [-f | --host_file <hostfile>]

gpmemwatcher --version

gpmemwatcher -h | --help
```

Description

The `gpmemwatcher` utility is a daemon that runs on all servers of a WarehousePG cluster. It tracks the memory usage of each process by collecting the output of the `ps` command every 60 seconds. It is a low impact process that only consumes 4 MB of memory. It will generate approximately 30 MB of data over a 24-hour period.

You may use this utility if WarehousePG is reporting `Out of memory` errors and causing segments to go down or queries to fail. You collect the memory usage information of one or multiple servers within the WarehousePG cluster with `gpmemwatcher` and then use gpmemreport to analyze the files collected.

Options

-f | --host_file hostfile Indicates the hostfile input file that lists the hosts from which the utility should collect memory usage information. The file must include the hostnames and a working directory that exists on each one of the hosts. For example:

```
```
cdw:/home/gpadmin/gpmemwatcher_dir/working
sdw1:/home/gpadmin/gpmemwatcher_dir/working
sdw2:/home/gpadmin/gpmemwatcher_dir/working
sdw3:/home/gpadmin/gpmemwatcher_dir/working
sdw4:/home/gpadmin/gpmemwatcher_dir/working
```
```

--stop Stops all the `gpmemwatcher` processes, generates `.gz` data files in the current directory, and removes all the work files from all the hosts.

--version Displays the version of this utility.

-h | --help Displays the online help.

Examples

Example 1: Start the utility specifying the list of hosts from which to collect the information

Create the file `/home/gpadmin/hostmap.txt` that contains the following:

```
cdw:/home/gpadmin/gpmemwatcher_dir/working
sdw1:/home/gpadmin/gpmemwatcher_dir/working
sdw2:/home/gpadmin/gpmemwatcher_dir/working
sdw3:/home/gpadmin/gpmemwatcher_dir/working
sdw4:/home/gpadmin/gpmemwatcher_dir/working
```

Make sure that the path `/home/gpadmin/gpmemwatcher_dir/working` exists on all hosts.

Start the utility:

```
$ gpmemwatcher -f /home/gpadmin/hostmap.txt
```

Example 2: Stop utility and dump the resulting into a `.gz` file

Stop the utility you started in Example 1:

```
$ gpmemwatcher -f /home/gpadmin/hostmap.txt --stop
```

The results `.gz` files will be dumped into the directory where you are running the command:

```
$ [gpadmin@gpdb-m]$ ls -thrl
-rw-rw-r--. 1 gpadmin gpadmin 2.8K Nov 19 15:17 cdw.ps.out.gz
-rw-rw-r--. 1 gpadmin gpadmin 2.8K Nov 19 15:17 sdw1.ps.out.gz
-rw-rw-r--. 1 gpadmin gpadmin 2.8K Nov 19 15:17 sdw2.ps.out.gz
-rw-rw-r--. 1 gpadmin gpadmin 2.8K Nov 19 15:17 sdw3.ps.out.gz
-rw-rw-r--. 1 gpadmin gpadmin 2.8K Nov 19 15:17 sdw4.ps.out.gz
```

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See Also

gpmemreport

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7.7.2.22 gpmovemirrors

Moves mirror segment instances to new locations.

Synopsis

```
gpmovemirrors -i <move_config_file> [-d <coordinator_data_directory>]
          [-l <logfile_directory>] [-b <segment_batch_size>]
          [-B <batch_size>] [-v] [--hba-hostnames <boolean>] [-a]

gpmovemirrors -?

gpmovemirrors --version
```

Description

The `gpmovemirrors` utility moves mirror segment instances to new locations. You may want to move mirrors to new locations to optimize distribution or data storage.

By default, the utility will prompt you for the file system location(s) where it will move the mirror segment data directories.

You must make sure that the user who runs `gpmovemirrors` (the `gpadmin` user) has permissions to write to the data directory locations specified. You may want to create these directories on the segment hosts and `chown` them to the appropriate user before running `gpmovemirrors`.

Options

-a (do not prompt)

Do not prompt the user for confirmation.

-b segment_batch_size

The maximum number of segments per host to operate on in parallel. Valid values are `1` to `128`. If not specified, the utility will start recovering up to 64 segments in parallel on each host.

-B batch_size

The number of hosts to work on in parallel. If not specified, the utility will start working on up to 16 hosts in parallel. Valid values are `1` to `64`.

-d coordinator_data_directory

The coordinator data directory. If not specified, the value set for `$COORDINATOR_DATA_DIRECTORY` will be used.

--hba-hostnames boolean

Optional. Controls whether this utility uses IP addresses or host names in the `pg_hba.conf` file when updating this file with addresses that can connect to WarehousePG. When set to 0 -- the default value -- this utility uses IP addresses when updating this file. When set to 1, this utility uses host names when updating this file. For consistency, use the same value that was specified for `HBA_HOSTNAMES` when the WarehousePG cluster was initialized. For information about how WarehousePG resolves host names in the `pg_hba.conf` file, see Configuring Client Authentication.

-i move_config_file

A configuration file containing information about which mirror segments to move, and where to move them.

You must have one mirror segment listed for each primary segment in the system. Each line inside the configuration file has the following format (as per attributes in the `gp_segment_configuration` catalog table):

```
<old_address>|<port>|<data_dir> <new_address>|<port>|<data_dir>
```

Where `<old_address>` and `<new_address>` are the host names or IP addresses of the segment hosts, `<port>` is the communication port, and `<data_dir>` is the segment instance data directory.

-l logfile_directory

The directory to write the log file. Defaults to `~/gpAdminLogs`.

-v (verbose)

Sets logging output to verbose.

--version (show utility version)

Displays the version of this utility.

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-? (help)

Displays the online help.

Examples

Moves mirrors from an existing WarehousePG cluster to a different set of hosts:

```
$ gpmovemirrors -i move_config_file
```

Where the `move_config_file` looks something like this:

```
sdw2|50000|/data2/mirror/gpseg0 sdw3|50000|/data/mirror/gpseg0
sdw2|50001|/data2/mirror/gpseg1 sdw4|50001|/data/mirror/gpseg1
sdw3|50002|/data2/mirror/gpseg2 sdw1|50002|/data/mirror/gpseg2
```

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7.7.2.23 gprecoverseg

Recovers a primary or mirror segment instance that has been marked as down (if mirroring is enabled).

Synopsis

```
gprecoverseg [[-p <new_recover_host>[,...]] | -i <recover_config_file>] [-d <coordinator_data_directory>]
             [-b <segment_batch_size>] [-B <batch_size>] [-F [-s]] [-a] [-q] [--differential]
               [--hba-hostnames <boolean>]
             [--no-progress] [-l <logfile_directory>] [--max-rate <max_rate>]

gprecoverseg -r [--replay-lag <replay_lag>] [--disable-replay-lag]

gprecoverseg -o <output_recover_config_file>
             [-p <new_recover_host>[,...]]

gprecoverseg -? | -h | --help

gprecoverseg -v | --verbose

gprecoverseg --version
```

Description

In a system with mirrors enabled, the `gprecoverseg` utility reactivates a failed segment instance and identifies the changed database files that require resynchronization. Once `gprecoverseg` completes this process, the system goes into `Not in Sync` mode until the recovered segment is brought up to date. The system is online and fully operational during resynchronization.

During an incremental recovery (the `-F` option is not specified), if `gprecoverseg` detects a segment instance with mirroring deactivated in a system with mirrors activated, the utility reports that mirroring is deactivated for the segment, does not attempt to recover that segment instance, and continues the recovery process.

A segment instance can fail for several reasons, such as a host failure, network failure, or disk failure. When a segment instance fails, its status is marked as `d` (down) in the WarehousePG cluster catalog, and its mirror is activated in `Not in Sync` mode. In order to bring the failed segment instance back into operation again, you must first correct the problem that made it fail in the first place, and then recover the segment instance in WarehousePG using `gprecoverseg`.

> **Note** If incremental recovery was not successful and the down segment instance data is not corrupted, contact Support.

Segment recovery using `gprecoverseg` requires that you have an active mirror to recover from. For systems that do not have mirroring enabled, or in the event of a double fault (a primary and mirror pair both down at the same time) — you must take manual steps to recover the failed segment instances and then perform a system restart to bring the segments back online. For example, this command restarts a system.

```
gpstop -r
```

By default, a failed segment is recovered in place, meaning that the system brings the segment back online on the same host and data directory location on which it was originally configured. In this case, use the following format for the recovery configuration file (using `-i`). Note that `failed_host_name` is an optional parameter.

```
<failed_host_name>|<failed_host_address>|<port>|<data_directory>
```

In some cases, this may not be possible (for example, if a host was physically damaged and cannot be recovered). In this situation, `gprecoverseg` allows you to recover failed segments to a completely new host (using `-p`), on an alternative data directory location on your remaining live segment hosts (using `-s`), or by supplying a recovery configuration file (using `-i`) in the following format. The word <SPACE> indicates the location of a required space. Do not add additional spaces. The parameter `failed_host_name` is optional.

```
<failed_host_name>|<failed_host_address>|<port>|<data_directory><SPACE><recovery_host_name>|<recovery_host_address>|<port>|<data_directory>
```

See the `-i` option below for details and examples of a recovery configuration file.

The `gp_segment_configuration` system catalog table can help you determine your current segment configuration so that you can plan your mirror recovery configuration. For example, run the following query:

```
=# SELECT dbid, content, address, port, datadir
   FROM gp_segment_configuration
   ORDER BY dbid;
```

The new recovery segment host must be pre-installed with the WarehousePG software and configured exactly the same as the existing segment hosts. A spare data directory location must exist on all currently configured segment hosts and have enough disk space to accommodate the failed segments.

The recovery process marks the segment as up again in the WarehousePG cluster catalog, and then initiates the resynchronization process to bring the transactional state of the segment up-to-date with the latest changes. The system is online and available during `Not in Sync` mode.

Options

-a (do not prompt) : Do not prompt the user for confirmation.

-b segment_batch_size : The maximum number of segments per host to operate on in parallel. Valid values are `1` to `128`. If not specified, the utility will start recovering up to 64 segments in parallel on each host.

-B batch_size : The number of hosts to work on in parallel. If not specified, the utility will start working on up to 16 hosts in parallel. Valid values are `1` to `64`.

-d coordinator_data_directory : Optional. The coordinator host data directory. If not specified, the value set for `$COORDINATOR_DATA_DIRECTORY` will be used.

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-F (full recovery) : Optional. Perform a full copy of the active segment instance in order to recover the failed segment, rather than the default behavior of copying only the changes that occurred while the segment was down.

```
>**Caution**
>A full recovery deletes the data directory of the down segment instance before copying the data from the active (current primary) segment instance. Before performing a full recovery, ensure that the segment failure did not cause data corruption and that any host segment disk issues have been fixed.

Also, for a full recovery, the utility does not restore custom files that are stored in the segment instance data directory even if the custom files are also in the active segment instance. You must restore the custom files manually. For example, when using the `gpfdists` protocol (`gpfdist` with SSL encryption) to manage external data, client certificate files are required in the segment instance `$PGDATA/gpfdists` directory. These files are not restored. For information about configuring `gpfdists`, see [Encrypting gpfdist Connections](../../security_guide/encryption.html).

Use the `-s` option to output a new line once per second for each segment. Alternatively, use the `--no-progress` option to completely deactivate progress reports. To avoid copying the entire contents of the data directory during a full recovery after a previous full recovery failed, use `gprecoverseg`s

speed up the amount of time full recovery takes, use the `--differential` option to skip recovery of files and directories that have not changed since the last time `gprecoverseg` ran.
```

--differential (Differential recovery) : Optional. Perform a differential copy of the active segment instance in order to recover the failed segment. The default is to only copy over the incremental changes that occurred while the segment was down.

--hba-hostnames boolean : Optional. Controls whether this utility uses IP addresses or host names in the `pg_hba.conf` file when updating this file with addresses that can connect to WarehousePG. When set to 0 -- the default value -- this utility uses IP addresses when updating this file. When set to 1, this utility uses host names when updating this file. For consistency, use the same value that was specified for `HBA_HOSTNAMES` when the WarehousePG cluster was initialized. For information about how WarehousePG resolves host names in the `pg_hba.conf` file, see Configuring Client Authentication.

-i recover_config_file : Specifies the name of a file with the details about failed segments to recover.

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Each line in the config file specifies a segment to recover. This line can have one of three formats. In the event of in-place \(incremental\) recovery, enter one group of pipe-delimited fields in the line. For example:

```
failedAddress|failedPort|failedDataDirectory
```

or

```
failedHostname|failedAddress|failedPort|failedDataDirectory
```

For recovery to a new location, enter two groups of fields separated by a space in the line. The required space is indicated by <SPACE\>. Do not add additional spaces.

```
failedAddress|failedPort|failedDataDirectory<SPACE>newAddress|newPort|newDataDirectory
```

or

```
failedHostname|failedAddress|failedPort|failedDataDirectory<SPACE>newHostname|newAddress|newPort|newDataDirectory
```

To do mix recovery, include a field with values I/D/F/i/d/f on each line. Default is incremental recovery if recovery_type field is not provided.

```
recoveryType|failedAddress|failedPort|failedDataDirectory
```

recoveryType field supports below values:
    I/i for incremental recovery
    D/d for differential recovery
    F/f for full recovery

> **Note** Lines beginning with `#` are treated as comments and ignored.

Examples

In-place \(incremental\) recovery of a single mirror

```
sdw1-1|50001|/data1/mirror/gpseg16
```

Recovery of a single mirror to a new host

```
sdw1-1|50001|/data1/mirror/gpseg16<SPACE>sdw4-1|50001|/data1/recover1/gpseg16
```

In-place recovery of down mirrors with recovery type:

```
sdw1-1|50001|/data1/mirror/gpseg1   // Does incremental recovery (By default)
I|sdw1-1|50001|/data1/mirror/gpseg1   // Does incremental recovery
i|sdw1-1|50001|/data1/mirror/gpseg1   // Does incremental recovery
D|sdw2-1|50002|/data1/mirror/gpseg2   // Does Differential recovery
d|sdw2-1|50002|/data1/mirror/gpseg2   // Does Differential recovery
F|sdw3-1|50003|/data1/mirror/gpseg3   // Does Full recovery
f|sdw3-1|50003|/data1/mirror/gpseg3   // Does Full recovery
```

Obtaining a Sample File

You can use the `-o` option to output a sample recovery configuration file to use as a starting point. The output file lists the currently invalid segments and their default recovery location. This file format can be used with the `-i` option for in-place \(incremental\) recovery.

-l logfile_directory : The directory to write the log file. Defaults to `~/gpAdminLogs`.

--max-rate <max_rate>

: Optional. Specifies the maximum bandwidth rate for a full recovery of failed segments. The rate is specified in kB/s. You may use the suffix `k` or `M` to signify kB/s or MB/s. The valid values ranges from 32kB/s to 1048576kB/s (1024MB/s). The default value is to use the entire available network bandwidth to perform the full recovery. Note that incremental and differential recoveries do not support this option, they use the entire available network bandwidth.

-o output_recover_config_file : Specifies a file name and location to output a sample recovery configuration file. This file can be edited to supply alternate recovery locations if needed. The following example outputs the default recovery configuration file:

```
$ gprecoverseg -o /home/gpadmin/recover_config_file
```

-p new_recover_host[,...] : Specifies a new host outside of the currently configured WarehousePG cluster on which to recover invalid segments.

: The new host must have the WarehousePG software installed and configured, and have the same hardware and OS configuration as the current segment hosts (same OS version, locales, `gpadmin` user account, data directory locations created, ssh keys exchanged, number of network interfaces, network interface naming convention, and so on). Specifically, the WarehousePG binaries must be installed, the new host must be able to connect password-less with all segments including the WarehousePG coordinator, and any other WarehousePG specific OS configuration parameters must be applied.

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: > **Note** In the case of multiple failed segment hosts, you can specify the hosts to recover with a comma-separated list. However, it is strongly recommended to recover one host at a time. If you must recover more than one host at a time, then it is critical to ensure that a double fault scenario does not occur, in which both the segment primary and corresponding mirror are offline.

-q (no screen output) : Run in quiet mode. Command output is not displayed on the screen, but is still written to the log file.

-r (rebalance segments) : After a segment recovery, segment instances may not be returned to the preferred role that they were given at system initialization time. This can leave the system in a potentially unbalanced state, as some segment hosts may have more active segments than is optimal for top system performance. This option rebalances primary and mirror segments by returning them to their preferred roles. All segments must be valid and resynchronized before running `gprecoverseg -r`. If there are any in progress queries, they will be cancelled and rolled back.

--replay-lag : Replay lag(in GBs) allowed on mirror when rebalancing the segments. Default is 10 GB. If the replay_lag (flush_lsn-replay_lsn) is more than the value provided with this option then rebalance will be aborted.

--disable-replay-lag : Disable replay lag check when rebalancing segments

-s (sequential progress) : Show `pg_basebackup` or `pg_rewind` progress sequentially instead of in-place. Useful when writing to a file, or if a tty does not support escape sequences. The default is to show progress in-place.

--no-progress : Suppresses progress reports from the `pg_basebackup`, `pg_rewind`, or `rsync` utility. The default is to display progress.

--differential : Optional. During a full recovery, copy from the primary segment to the mirror segment only the files and directories that changed since the segment failed. You may use the `--differential` option for in-place full recovery only. See Recovery Scenarios for more information on in-place recovery versus recovery to a different host.

```
>**Note**
>The `--differential` option cannot be combined with any of the following `gprecoverseg` options: `-i`, `-o`, `-F`, or `-p`.
```

-v | --verbose : Sets logging output to verbose.

--version : Displays the version of this utility.

-? | -h | --help : Displays the online help.

Examples

Example 1: Recover Failed Segments in Place

Recover any failed segment instances in place:

```
$ gprecoverseg
```

Example 2: Rebalance Failed Segments If Not in Preferred Roles

First, verify that all segments are up and running, reysynchronization has completed, and there are segments **not** in preferred roles:

```
$ gpstate -e
```

Then, if necessary, rebalance the segments:

```
$ gprecoverseg -r
```

Example 3: Recover Failed Segments to a Separate Host

Recover any failed segment instances to a newly configured new segment host:

```
$ gprecoverseg -i <recover_config_file>
```

See Also

gpstart, gpstop

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7.7.2.24 gpreload

Reloads WarehousePG table data sorting the data based on specified columns.

> **Note** The `gpreload` utility is deprecated and will be removed in the next major release of WarehousePG. UseALTER TABLE REPACK BY COLUMNS to physically reorder a table based on one or more columns.

Synopsis

```
gpreload -d <database> [-p <port>] {-t | --table-file} <path_to_file> [-a]

gpreload -h

gpreload --version
```

Description

The `gpreload` utility reloads table data with column data sorted. For tables that were created with the table storage option `appendoptimized=TRUE` and compression enabled, reloading the data with sorted data can improve table compression. You specify a list of tables to be reloaded and the table columns to be sorted in a text file.

Compression is improved by sorting data when the data in the column has a relatively low number of distinct values when compared to the total number of rows.

For a table being reloaded, the order of the columns to be sorted might affect compression. The columns with the fewest distinct values should be listed first. For example, listing state then city would generally result in better compression than listing city then state.

```
public.cust_table: state, city
public.cust_table: city, state
```

For information about the format of the file used with `gpreload`, see the `--table-file` option.

Notes

To improve reload performance, indexes on tables being reloaded should be removed before reloading the data.

Running the `ANALYZE` command after reloading table data might query performance because of a change in the data distribution of the reloaded data.

For each table, the utility copies table data to a temporary table, truncates the existing table data, and inserts data from the temporary table to the table in the specified sort order. Each table reload is performed in a single transaction.

For a partitioned table, you can reload the data of a leaf partition. However, data is inserted from the root partitioned table, which acquires a `ROW EXCLUSIVE` lock on the entire table.

Options

-a (do not prompt) Optional. If specified, the `gpreload` utility does not prompt the user for confirmation.

-d database The database that contains the tables to be reloaded. The `gpreload` utility connects to the database as the user running the utility.

-p port The WarehousePG coordinator port. If not specified, the value of the `PGPORT` environment variable is used. If the value is not available, an error is returned.

{-t | --table-file } path_to_file The location and name of file containing list of schema qualified table names to reload and the column names to reorder from the WarehousePG. Only user defined tables are supported. Views or system catalog tables are not supported.

If indexes are defined on table listed in the file, `gpreload` prompts to continue.

Each line specifies a table name and the list of columns to sort. This is the format of each line in the file:

```
schema.table_name: column [desc] [, column2 [desc] ... ]
```

The table name is followed by a colon (:) and then at least one column name. If you specify more than one column, separate the column names with a comma. The columns are sorted in ascending order. Specify the keyword `desc` after the column name to sort the column in descending order.

Wildcard characters are not supported.

If there are errors in the file, `gpreload` reports the first error and exits. No data is reloaded.

The following example reloads three tables:

```
```
public.clients: region, state, rep_id desc
public.merchants: region, state
test.lineitem: group, assy, whse
```
```

In the first table `public.clients`, the data in the `rep_id` column is sorted in descending order. The data in the other columns are sorted in ascending order.

--version (show utility version) Displays the version of this utility.

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-? (help) Displays the online help.

Example

This example command reloads the tables in the database `mytest` that are listed in the file `data-tables.txt`.

```
gpreload -d mytest --table-file data-tables.txt
```

See Also

`CREATE TABLE` in the *WarehousePG Reference Guide*

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7.7.2.25 gprestore

Restore a WarehousePG backup set that was created using the `gpbackup` utility. By default `gprestore` will read the metadata and DDL files located in the Coordinator host data directory, and will load the CSV formatted table data stored locally on each segment hosts.

Synopsis

```
gprestore --timestamp <YYYYMMDDHHMMSS>
   [--backup-dir <directory>]
   [--copy-queue-size <int>]
   [--create-db]
   [--data-only]
   [--debug]
   [--exclude-schema <schema_name> [--exclude-schema <schema_name> ...]]
   [--exclude-schema-file <file_name>]
   [--exclude-table <schema.table> [--exclude-table <schema.table> ...]]
   [--exclude-table-file <file_name>]
   [--help]
   [--include-schema <schema_name> [--include-schema <schema_name> ...]]
   [--include-schema-file <file_name>]
   [--include-table <schema.table> [--include-table <schema.table> ...]]
   [--include-table-file <file_name>]
   [--incremental]
   [--jobs <int>]
   [--metadata-only]
   [--on-error-continue]
   [--plugin-config <config_file_location>]
   [--quiet]
   [--redirect-db <database_name>]
   [--redirect-schema <schema_name>]
   [--report-dir]
   [--resize-cluster]
   [--run-analyze]
   [--timestamp <YYYYMMDDHHMMSS>]
   [--truncate-table]
   [--verbose]
   [--version]
   [--with-globals]
   [--with-stats]


gprestore --help
```

`gpbackup` reference

Description

To use `gprestore` to restore from a backup set, you must include the `--timestamp` option to specify the exact timestamp value (`YYYYMMDDHHMMSS`) of the backup set to restore. If you specified a custom `--backup-dir` to consolidate the backup files, include the same `--backup-dir` option with `gprestore` to locate the backup files.

If the backup you specify is an incremental backup, you need a complete set of backup files (a full backup and any required incremental backups). `gprestore` ensures that the complete backup set is available before attempting to restore a backup.

Important: For incremental backup sets, the backups must be on a single device. For example, a backup set must all be on a Data Domain system.

When restoring from a backup set, `gprestore` restores to a database with the same name as the name specified when creating the backup set. If the target database exists and a table being restored exists in the database, the restore operation fails. Include the `--create-db` option if the target database does not exist in the cluster. You can optionally restore a backup set to a different database by using the `--redirect-db` option.

When restoring a backup set that contains data from some leaf partitions of a partitioned tables, the partitioned table is restored along with the data for the leaf partitions. For example, you create a backup with the `gpbackup` option `--include-table-file` and the text file lists some leaf partitions of a partitioned table. Restoring the backup creates the partitioned table and restores the data only for the leaf partitions listed in the file.

By default, only database objects in the backup set are restored. WarehousePG system objects are automatically included in a `gpbackup` backup set, but these objects are only restored if you include the `--with-globals` option to `gprestore` .

During a restore operation, automatic updating of table statistics is deactivated for the tables being restored. If you backed up query plan statistics using the `--with-stats` option, you can restore those statistics by providing `--with-stats` to `gprestore` . If you did not use `--with-stats` during a backup, or you want to collect current statistics during the restore operation, you can use the `--run-analyze` option to run `ANALYZE` on the restored tables.

When a materialized view is restored, the data is not restored. To populate the materialized view with data, use `REFRESH MATERIALIZED VIEW` . The tables that are referenced by the materialized view definition must be available. The `gprestore` log file lists the materialized views that were restored and the `REFRESH MATERIALIZED VIEW` commands that are used to populate the materialized views with data.

Performance of restore operations can be improved by creating multiple parallel connections to restore table data and metadata. By default `gprestore` uses 1 connection, but you can increase this number with the `--jobs` option for large restore operations.

When a restore operation completes, `gprestore` returns a status code.

`gprestore` can send status email notifications after a back up operation completes. You specify when the utility sends the mail and the email recipients in a configuration file.

Note: This utility uses secure shell (SSH) connections between systems to perform its tasks. In large WarehousePG deployments, cloud deployments, or deployments with a large number of segments per host, this utility may exceed the host's maximum threshold for unauthenticated connections. Consider updating the SSH `MaxStartups` and `MaxSessions` configuration parameters to increase this threshold. For more information about SSH configuration options, refer to the SSH documentation for your Linux distribution.

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Options

--timestamp YYYYMMDDHHMMSS

Required. Specifies the timestamp of the `gpbackup` backup set to restore. By default `gprestore` tries to locate metadata files for the timestamp on the WarehousePG Coordinator host in the $COORDINATOR_DATA_DIRECTORY/backups/YYYYMMDD/YYYYMMDDhhmmss/ directory, and CSV data files in the `<seg_dir>/backups/YYYYMMDD/YYYYMMDDhhmmss/` directory of each segment host.

--backup-dir directory

Optional. Sources all backup files (metadata files and data files) from the specified directory. You must specify directory as an absolute path (not relative). If you do not supply this option, `gprestore` tries to locate metadata files for the timestamp on the WarehousePG Coordinator host in the $COORDINATOR_DATA_DIRECTORY/backups/YYYYMMDD/YYYYMMDDhhmmss/ directory. CSV data files must be available on each segment in the `<seg_dir>/backups/YYYYMMDD/YYYYMMDDhhmmss/` directory. Include this option when you specify a custom backup directory with `gpbackup`.

You cannot combine this option with the option `--plugin-config`.

--copy-queue-size int

Optional. Specifies the number of `COPY` commands `gprestore` should enqueue when restoring a backup set. This option optimizes restore performance by reducing the amount of time spent initializing `COPY` commands. If you do not set this option to 2 or greater, `gprestore` enqueues 1 `COPY` command at a time.

--create-db

Optional. Creates the database before restoring the database object metadata.

The database is created by cloning the empty standard system database `template0`.

--data-only

Optional. Restores table data from a backup created with the `gpbackup` utility, without creating the database tables. This option assumes the tables exist in the target database. To restore data for a specific set of tables from a backup set, you can specify an option to include tables or schemas or exclude tables or schemas. Specify the `--with-stats` option to restore table statistics from the backup.

The backup set must contain the table data to be restored. For example, a backup created with the `gpbackup` option `--metadata-only` does not contain table data.

`SEQUENCE` values are updated to match the values taken at the time of the backup.

To restore only database tables, without restoring the table data, see the option `--metadata-only`.

--debug

Optional. Displays verbose and debug log messages during a restore operation.

--exclude-schema schema_name

Optional. Specifies a database schema to exclude from the restore operation. You can specify this option multiple times. You cannot combine this option with the option `--include-schema`, `--include-schema-file`, or a table filtering option such as `--include-table`.

--exclude-schema-file file_name

Optional. Specifies a text file containing a list of schemas to exclude from the backup. Each line in the text file must define a single schema. The file must not include trailing lines. If a schema name uses any character other than a lowercase letter, number, or an underscore character, then you must include that name in double quotes. You cannot combine this option with the option `--include-schema` or `--include-schema-file`, or a table filtering option such as `--include-table`.

--exclude-table schema.table

Optional. Specifies a table to exclude from the restore operation. You can specify this option multiple times. The table must be in the format `<schema-name>.<table-name>`. If a table or schema name uses any character other than a lowercase letter, number, or an underscore character, then you must include that name in double quotes. You can specify this option multiple times. If the table is not in the backup set, the restore operation fails. You cannot specify a leaf partition of a partitioned table.

You cannot combine this option with the option `--exclude-schema`, `--exclude-schema-file`, or another a table filtering option such as `--include-table`.

--exclude-table-file file_name

Optional. Specifies a text file containing a list of tables to exclude from the restore operation. Each line in the text file must define a single table using the format `<schema-name>.<table-name>`. The file must not include trailing lines. If a table or schema name uses any character other than a lowercase letter, number, or an underscore character, then you must include that name in double quotes. If a table is not in the backup set, the restore operation fails. You cannot specify a leaf partition of a partitioned table.

You cannot combine this option with the option `--exclude-schema`, `--exclude-schema-file`, or another a table filtering option such as `--include-table`.

--help

Displays the online help.

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--include-schema schema_name

Optional. Specifies a database schema to restore. You can specify this option multiple times. If you specify this option, any schemas that you specify must be available in the backup set. Any schemas that are not included in subsequent `--include-schema` options are omitted from the restore operation.

If a schema that you specify for inclusion exists in the database, the utility issues an error and continues the operation. The utility fails if a table being restored exists in the database.

You cannot use this option if objects in the backup set have dependencies on multiple schemas.

--include-schema-file file_name

Optional. Specifies a text file containing a list of schemas to restore. Each line in the text file must define a single schema. The file must not include trailing lines. If a schema name uses any character other than a lowercase letter, number, or an underscore character, then you must include that name in double quotes.

The schemas must exist in the backup set. Any schemas not listed in this file are omitted from the restore operation.

You cannot use this option if objects in the backup set have dependencies on multiple schemas.

--include-table schema.table

Optional. Specifies a table to restore. The table must be in the format `<schema-name>.<table-name>`. You can specify this option multiple times. You cannot specify a leaf partition of a partitioned table.

You can also specify the qualified name of a sequence, a view, or a materialized view.

If you specify this option, the utility does not automatically restore dependent objects. You must also explicitly specify the dependent objects that are required. For example if you restore a view or a materialized view, you must also restore the tables that the view or the materialized view uses. If you restore a table that uses a sequence, you must also restore the sequence. The dependent objects must exist in the backup set.

You cannot combine this option with a schema filtering option such as `--include-schema`, or another table filtering option such as `--exclude-table-file`.

--include-table-file file_name

Optional. Specifies a text file containing a list of tables to restore. Each line in the text file must define a single table using the format `<schema-name>.<table-name>`. The file must not include trailing lines. Any tables not listed in this file are omitted from the restore operation. You cannot specify a leaf partition of a partitioned table.

You can also specify the qualified name of a sequence, a view, or a materialized view.

If you specify this option, the utility does not automatically restore dependent objects. You must also explicitly specify dependent objects that are required. For example, if you restore a view or a materialized view, you must also specify the tables that the view or the materialized uses. If you specify a table that uses a sequence, you must also specify the sequence. The dependent objects must exist in the backup set.

For a materialized view, the data is not restored. To populate the materialized view with data, you must use `REFRESH MATERIALIZED VIEW` and the tables that are referenced by the materialized view definition must be available.

If you use the `--include-table-file` option, `gprestore` does not create roles or set the owner of the tables. The utility restores table indexes and rules. Triggers are also restored but are not supported in WarehousePG.

--incremental

Optional. Requires the `--data-only option`. Restores only the table data in the incremental backup specified by the `--timestamp` option. Table data is not restored from previous incremental backups in the backup set.
Warning: This is a Beta feature and is not supported in a production environment.

An incremental backup contains the following table data that can be restored.

- Data from all heap tables.
- Data from append-optimized tables that have been modified since the previous backup.
- Data from leaf partitions that have been modified from the previous backup.

When this option is specified, `gprestore` restores table data by truncating the table and reloading data into the table. `SEQUENCE` values are then updated to match the values taken at the time of the backup.

Before performing the restore operation, `gprestore` ensures that the tables being restored exist. If a table does not exist, `gprestore` returns an error and exits. If the `--on-error-continue` option is specified, `gprestore` logs missing tables and attempts to complete the restore operation.

> **Warning**
>
> When this option is specified, `gpbackup` assumes that no changes have been made to the table definitions of the tables being restored, such as adding or removing columns.--truncate-table

Optional. Truncate data from a set of tables before restoring the table data from a backup. This option lets you replace table data with data from a backup. Otherwise, table data might be duplicated.

You must specify the set of tables with either the option `--include-table` or `--include-table-file`. You must also specify `--data-only` to restore table data without creating the tables.

You can use this option with the `--redirect-db` option. You cannot use this option with `--redirect-schema`.

--jobs int

Optional. Specifies the number of parallel connections to use when restoring table data and metadata. By default, `gprestore` uses 1 connection. Increasing this number can improve the speed of restoring data. **Note:** If you used the `gpbackup --single-data-file` option to combine table backups into a single file per segment, you cannot set `--jobs` to a value higher than 1 to perform a parallel restore operation.

--metadata-only

Optional. Creates database tables from a backup created with the `gpbackup` utility, but does not restore the table data. This option assumes the tables do not exist in the target database. To create a specific set of tables from a backup set, you can specify an option to include tables or schemas or exclude tables or schemas. Specify the option `--with-globals` to restore the WarehousePG system objects.

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The backup set must contain the DDL for tables to be restored. For example, a backup created with the `gpbackup` option `--data-only` does not contain the DDL for tables.

--on-error-continue

Optional. Specify this option to continue the restore operation if an SQL error occurs when creating database metadata (such as tables, roles, or functions) or restoring data. If another type of error occurs, the utility exits. The default is to exit on the first error.

When this option is included, the utility displays an error summary and writes error information to the `gprestore` log file and continues the restore operation. The utility also creates text files in the backup directory that contain the list of tables that generated SQL errors.

- Tables with metadata errors - `gprestore_<backup-timestamp>_<restore-time>_error_tables_metadata`
- Tables with data errors - `gprestore_<backup-timestamp>_<restore-time>_error_tables_data`

--plugin-config config-file_location

Specify the location of the `gpbackup` plugin configuration file, a YAML-formatted text file. The file contains configuration information for the plugin application that `gprestore` uses during the restore operation.

If you specify the `--plugin-config` option when you back up a database, you must specify this option with configuration information for a corresponding plugin application when you restore the database from the backup.

You cannot combine this option with the option `--backup-dir`.

--quiet

Optional. Suppress all non-warning, non-error log messages.

--redirect-db database_name

Optional. Restore to the specified database_name instead of to the database that was backed up.

--redirect-schema schema_name

Optional. Restore data in the specified schema instead of the original schemas. The specified schema must already exist. If the data being restored is in multiple schemas, all the data is redirected into the specified schema.

This option must be used with an option that includes tables or schemas: `--include-table`, `--include-table-file`, `--include-schema`, or `--include-schema-file`.

You cannot use this option with an option that excludes schemas or tables such as `--exclude-schema` or `--exclude-table`.

You can use this option with the `--metadata-only` or `--data-only` options.

--report-dir /path/to/report

Optional. The absolute path of the directory to which restore report and error tables will be written.

--resize-cluster

Optional. Invoke this option to enable restoring data to a cluster that has a different number of segments than the cluster from which the data was backed up.

Warning: This is a Beta feature and is not supported in a production environment.

> **Note**
>
> In order to enable the `--resize-cluster` feature for `gprestore`, the backup set must have been taking using using `gpbackup` 1.26 or later.

--run-analyze

Optional. Run `ANALYZE` on the tables that are restored. For a partitioned table, `ANALYZE` is run on the root partitioned table. If `--with-stats` was specified for the backup, those statistics are ignored. You cannot use this option with `--with-stats`.

If the backup being restored used the `gpbackup` option `--leaf-partition-data`, `gprestore` runs `ANALYZE` only on the individual leaf partitions that are restored, not the root partitioned table.

Depending the tables being restored, running `ANALYZE` on restored tables might increase the duration of the restore operation.

--timestamp YYYYMMDDHHMMSS

Required. Specifies the timestamp of the `gpbackup` backup set to restore. By default `gprestore` tries to locate metadata files for the timestamp on the WarehousePG Coordinator host in the $COORDINATOR_DATA_DIRECTORY/backups/YYYYMMDD/YYYYMMDDhhmmss/ directory, and CSV data files in the `<seg_dir>/backups/YYYYMMDD/YYYYMMDDhhmmss/` directory of each segment host.

--truncate-table

Optional. Removes existing data from the tables being restored, to eliminate the chance of duplicate data.

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--verbose

Optional. Displays verbose log messages during a restore operation.--versionOptional. Print the version number and exit.

--version

Optional. Displays the verison of the gprestore utility.

--with-globals

Optional. Restores WarehousePG system objects in the backup set, in addition to database objects.

--with-stats

Optional. Restore query plan statistics from the backup set. If the backup set was not created with the `--with-stats` option, an error is returned. Restored tables will only have statistics from the backup. You cannot use this option with `--run-analyze`.

To collect current statistics for the restored tables during the restore operation, use the `--run-analyze` option. As an alternative, you can run the `ANALYZE` command on the tables after the tables are restored.

Return Codes

One of these codes is returned after `gprestore` completes.

- 0 -- Restore completed with no problems.
- 1 -- Restore completed with non-fatal errors. See log file for more information.
- 2 -- Restore failed with a fatal error. See log file for more information.

Examples

Create the ww_customer database and restore all schemas and tables in the backup set for the indicated timestamp:

```
$ dropdb ww_customer
$ gprestore --timestamp 20250515182209 --create-db
```

Restore the backup set to the "customer" database instead of the "demo" database that was backed up:

```
$ createdb customer
$ gprestore --timestamp 20250515182209 --redirect-db customer
```

Restore global WarehousePG metadata and query plan statistics in addition to the database objects:

```
$ gprestore --timestamp 20250515182209 --create-db --with-globals --with-stats
```

Restore, using backup files that were created in the /mnt/nfs/wwhpg_backups directory, creating 8 parallel connections:

```
$ gprestore --backup-dir /mnt/nfs/whpg_backups/ --timestamp 20250515182209 --create-db --jobs 8
```

Restore only the `emea_customer` schema included in the backup set:

```
$ dropdb ww_customer
$ gprestore --include-schema emea_customer --backup-dir /mnt/nfs/whpg_backups/ --timestamp 20250515182209 --create-db
```

If you restore from an incremental backup set, all the required files in the backup set must be available to `gprestore`. For example, the following timestamp keys specify an incremental backup set. 20250518010000 is the full backup and the others are incremental backups.

```
20250518010000 (full backup, Sunday 1am)
20250519020000 (incremental backup, Monday 2am)
20250520030000 (incremental backup, Tuesday 3am)
20250521040000 (incremental backup, Wedndesday 4am)
20250522050000 (incremental backup, Thursday 5am)
20250523060000 (incremental backup, Friday 6am)
20250524070000 (incremental backup, Saturday 7am)
```

The following `gprestore` command specifies the timestamp `20250521040000` (Wednesday). The incremental backup with the timestamps `20250520030000` (Tuesday), `20250519020000` (Monday) and the full backup `20250518010000` (Sunday) must be available to perform a restore.

```
$ gprestore --timestamp 20250521040000 --redirect-db customer_incra --create-db
```

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See Also

gpbackup

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7.7.2.26 gpssh

Provides SSH access to multiple hosts at once.

Synopsis

```
gpssh { -f <hostfile_gpssh> | - h <hostname> [-h <hostname> ...] } \[-s\] [-e]
      [-d <seconds>] [-t <multiplier>] [-v]
      [<bash_command>]

gpssh -?

gpssh --version
```

Description

The `gpssh` utility allows you to run bash shell commands on multiple hosts at once using SSH (secure shell). You can run a single command by specifying it on the command-line, or omit the command to enter into an interactive command-line session.

To specify the hosts involved in the SSH session, use the `-f` option to specify a file containing a list of host names, or use the `-h` option to name single host names on the command-line. At least one host name (`-h`) or a host file (`-f`) is required. Note that the current host is ***not*** included in the session by default — to include the local host, you must explicitly declare it in the list of hosts involved in the session.

Before using `gpssh` , you must have a trusted host setup between the hosts involved in the SSH session. You can use the utility `gpssh-exkeys` to update the known host files and exchange public keys between hosts if you have not done so already.

If you do not specify a command on the command-line, `gpssh` will go into interactive mode. At the `gpssh` command prompt (`=>`), you can enter a command as you would in a regular bash terminal command-line, and the command will be run on all hosts involved in the session. To end an interactive session, press `CTRL` + `D` on the keyboard or type `exit` or `quit` .

If a user name is not specified in the host file, `gpssh` will run commands as the currently logged in user. To determine the currently logged in user, do a `whoami` command. By default, `gpssh` goes to `$HOME` of the session user on the remote hosts after login. To ensure commands are run correctly on all remote hosts, you should always enter absolute paths.

If you encounter network timeout problems when using `gpssh` , you can use `-d` and `-t` options or set parameters in the `gpssh.conf` file to control the timing that `gpssh` uses when validating the initial `ssh` connection. For information about the configuration file, see gpssh Configuration File.

Options

bash_command A bash shell command to run on all hosts involved in this session (optionally enclosed in quotes). If not specified, `gpssh` starts an interactive session.

-d (delay) seconds Optional. Specifies the time, in seconds, to wait at the start of a `gpssh` interaction with `ssh` . Default is `0.05` . This option overrides the `delaybeforesend` value that is specified in the `gpssh.conf` configuration file.

Increasing this value can cause a long wait time during `gpssh` startup.

-e (echo) Optional. Echoes the commands passed to each host and their resulting output while running in non-interactive mode.

-f hostfile_gpssh Specifies the name of a file that contains a list of hosts that will participate in this SSH session. The syntax of the host file is one host per line.

-h hostname Specifies a single host name that will participate in this SSH session. You can use the `-h` option multiple times to specify multiple host names.

-s Optional. If specified, before running any commands on the target host, `gpssh` sources the file `greenplum_path.sh` in the directory specified by the `$GPHOME` environment variable.

This option is valid for both interactive mode and single command mode.

-t multiplier Optional. A decimal number greater than 0 (zero) that is the multiplier for the timeout that `gpssh` uses when validating the `ssh` prompt. Default is `1` . This option overrides the `prompt_validation_timeout` value that is specified in the `gpssh.conf` configuration file.

Increasing this value has a small impact during `gpssh` startup.

-v (verbose mode) Optional. Reports additional messages in addition to the command output when running in non-interactive mode.

--version Displays the version of this utility.

-? (help) Displays the online help.

gpssh Configuration File

The `gpssh.conf` file contains parameters that let you adjust the timing that `gpssh` uses when validating the initial `ssh` connection. These parameters affect the network connection before the `gpssh` session runs commands with `ssh` . The location of the file is specified by the environment variable `COORDINATOR_DATA_DIRECTORY` . If the environment variable is not defined or the `gpssh.conf` file does not exist, `gpssh` uses the default values or the values set with the `-d` and `-t` options. For information about the environment variable, see the *WarehousePG Reference Guide*.

The `gpssh.conf` file is a text file that consists of a `[gpssh]` section and parameters. On a line, the `#` (pound sign) indicates the start of a comment. This is an example `gpssh.conf` file.

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```
[gpssh]
delaybeforesend = 0.05
prompt_validation_timeout = 1.0
sync_retries = 5
```

These are the `gpssh.conf` parameters.

delaybeforesend = seconds Specifies the time, in seconds, to wait at the start of a `gpssh` interaction with `ssh`. Default is 0.05. Increasing this value can cause a long wait time during `gpssh` startup. The `-d` option overrides this parameter.

prompt_validation_timeout = multiplier A decimal number greater than 0 (zero) that is the multiplier for the timeout that `gpssh` uses when validating the `ssh` prompt. Increasing this value has a small impact during `gpssh` startup. Default is `1`. The `-t` option overrides this parameter.

sync_retries = attempts A non-negative integer that specifies the maximum number of times that `gpssh` attempts to connect to a remote WarehousePG host. The default is 3. If the value is 0, `gpssh` returns an error if the initial connection attempt fails. Increasing the number of attempts also increases the time between retry attempts. This parameter cannot be configured with a command-line option.

The `-t` option also affects the time between retry attempts.

Increasing this value can compensate for slow network performance or segment host performance issues such as heavy CPU or I/O load. However, when a connection cannot be established, an increased value also increases the delay when an error is returned.

Examples

Start an interactive group SSH session with all hosts listed in the file `hostfile_gpssh`:

```
$ gpssh -f hostfile_gpssh
```

At the `gpssh` interactive command prompt, run a shell command on all the hosts involved in this session.

```
=> ls -a /data/primary/*
```

Exit an interactive session:

```
=> exit
=> quit
```

Start a non-interactive group SSH session with the hosts named `sdw1` and `sdw2` and pass a file containing several commands named `command_file` to `gpssh`:

```
$ gpssh -h sdw1 -h sdw2 -v -e < command_file
```

Run single commands in non-interactive mode on hosts `sdw2` and `localhost`:

```
$ gpssh -h sdw2 -h localhost -v -e 'ls -a /data/primary/*'
$ gpssh -h sdw2 -h localhost -v -e 'echo $GPHOME'
$ gpssh -h sdw2 -h localhost -v -e 'ls -1 | wc -l'
```

See Also

gpssh-exkeys, gpsync

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7.7.2.27 gpssh-exkeys

Exchanges SSH public keys between hosts.

Synopsis

```
gpssh-exkeys -f <hostfile_exkeys> | -h <hostname> [-h <hostname> ...]

gpssh-exkeys -e <hostfile_exkeys> -x <hostfile_gpexpand>

gpssh-exkeys -?

gpssh-exkeys --version
```

Description

The `gpssh-exkeys` utility exchanges SSH keys between the specified host names (or host addresses). This allows SSH connections between WarehousePG hosts and network interfaces without a password prompt. The utility is used to initially prepare a WarehousePG cluster for passwordless SSH access, and also to prepare additional hosts for passwordless SSH access when expanding a WarehousePG cluster.

Keys are exchanged as the currently logged in user. You run the utility on the coordinator host as the `gpadmin` user (the user designated to own your WarehousePG installation). WarehousePG management utilities require that the `gpadmin` user be created on all hosts in the WarehousePG cluster, and the utilities must be able to connect as that user to all hosts without a password prompt.

You can also use `gpssh-exkeys` to enable passwordless SSH for additional users, `root`, for example.

The `gpssh-exkeys` utility has the following prerequisites:

- The user must have an account on the coordinator, standby, and every segment host in the WarehousePG cluster.
- The user must have an `id_rsa` SSH key pair installed on the coordinator host.
- The user must be able to connect with SSH from the coordinator host to every other host machine without entering a password. (This is called "1-*n* passwordless SSH.")

You can enable 1-*n* passwordless SSH using the `ssh-copy-id` command to add the user's public key to each host's `authorized_keys` file. The `gpssh-exkeys` utility enables "*n*-*n* passwordless SSH," which allows the user to connect with SSH from any host to any other host in the cluster without a password.

To specify the hosts involved in an SSH key exchange, use the `-f` option to specify a file containing a list of host names (recommended), or use the `-h` option to name single host names on the command-line. At least one host name (`-h`) or a host file (`-f`) is required. Note that the local host is included in the key exchange by default.

To specify new expansion hosts to be added to an existing WarehousePG cluster, use the `-e` and `-x` options. The `-e` option specifies a file containing a list of existing hosts in the system that have already exchanged SSH keys. The `-x` option specifies a file containing a list of new hosts that need to participate in the SSH key exchange.

The `gpssh-exkeys` utility performs key exchange using the following steps:

- Adds the user's public key to the user's own `authorized_keys` file on the current host.
- Updates the `known_hosts` file of the current user with the host key of each host specified using the `-h`, `-f`, `-e`, and `-x` options.
- Connects to each host using `ssh` and obtains the user's `authorized_keys`, `known_hosts`, and `id_rsa.pub` files.
- Adds keys from the `id_rsa.pub` files obtained from each host to the `authorized_keys` file of the current user.
- Updates the `authorized_keys`, `known_hosts`, and `id_rsa.pub` files on all hosts with new host information (if any).

Options

-e hostfile_exkeys When doing a system expansion, this is the name and location of a file containing all configured host names and host addresses (interface names) for each host in your current WarehousePG cluster (coordinator, standby coordinator, and segments), one name per line without blank lines or extra spaces. Hosts specified in this file cannot be specified in the host file used with `-x`.

-f hostfile_exkeys Specifies the name and location of a file containing all configured host names and host addresses (interface names) for each host in your WarehousePG cluster (coordinator, standby coordinator and segments), one name per line without blank lines or extra spaces.

-h hostname Specifies a single host name (or host address) that will participate in the SSH key exchange. You can use the `-h` option multiple times to specify multiple host names and host addresses.

--version Displays the version of this utility.

-x hostfile_gpexpand When doing a system expansion, this is the name and location of a file containing all configured host names and host addresses (interface names) for each new segment host you are adding to your WarehousePG cluster, one name per line without blank lines or extra spaces. Hosts specified in this file cannot be specified in the host file used with `-e`.

-? (help) Displays the online help.

Examples

Exchange SSH keys between all host names and addresses listed in the file `hostfile_exkeys`:

```
$ gpssh-exkeys -f hostfile_exkeys
```

Exchange SSH keys between the hosts `sdw1`, `sdw2`, and `sdw3`:

```
$ gpssh-exkeys -h sdw1 -h sdw2 -h sdw3
```

Exchange SSH keys between existing hosts `sdw1`, `sdw2`, and `sdw3`, and new hosts `sdw4` and `sdw5` as part of a system expansion operation:

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```
$ cat hostfile_exkeys
cdw
cdw-1
cdw-2
scdw
scdw-1
scdw-2
sdw1
sdw1-1
sdw1-2
sdw2
sdw2-1
sdw2-2
sdw3
sdw3-1
sdw3-2
$ cat hostfile_gpexpand
sdw4
sdw4-1
sdw4-2
sdw5
sdw5-1
sdw5-2
$ gpssh-exkeys -e hostfile_exkeys -x hostfile_gpexpand
```

See Also

gpssh, gpsync

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7.7.2.28 gpstart

Starts a WarehousePG cluster.

Synopsis

```
gpstart [-d <coordinator_data_directory>] [-B <parallel_processes>] [-R]
        [-m] [-y] [-a] [-t <timeout_seconds>] [-l <logfile_directory>]
        [--skip-heap-checksum-validation]
        [-v | -q]

gpstart -? | -h | --help

gpstart --version
```

Description

The `gpstart` utility is used to start the WarehousePG server processes. When you start a WarehousePG cluster, you are actually starting several `postgres` database server listener processes at once (the coordinator and all of the segment instances). The `gpstart` utility handles the startup of the individual instances. Each instance is started in parallel.

As part of the startup process, the utility checks the consistency of heap checksum setting among the WarehousePG coordinator and segment instances, either enabled or deactivated on all instances. If the heap checksum setting is different among the instances, an error is returned and WarehousePG does not start. The validation can be deactivated by specifying the option `--skip-heap-checksum-validation`. For more information about heap checksums, see Enabling High Availability and Data Consistency Features in the *WarehousePG Administrator Guide*.

> **Note** Before you can start a WarehousePG cluster, you must have initialized the system using `gpinitsystem`. Enabling or deactivating heap checksums is set when you initialize the system and cannot be changed after initialization.

If the WarehousePG cluster is configured with a standby coordinator, and `gpstart` does not detect it during startup, `gpstart` displays a warning and lets you cancel the startup operation.

- If the `-a` option (deactivate interactive mode prompts) is not specified, `gpstart` displays and logs these messages:

  ```
  Standby host is unreachable, cannot determine whether the standby is currently acting as the coordinator. Received error: <error>
  Continue only if you are certain that the standby is not acting as the coordinator.
  ```

  It also displays this prompt to continue startup:

  ```
  Continue with startup Yy|Nn (default=N):
  ```

- If the `-a` option is specified, the utility does not start the system. The messages are only logged, and `gpstart` adds this log message:

  ```
  Non interactive mode detected. Not starting the cluster. Start the cluster in interactive mode.
  ```

If the standby coordinator is not accessible, you can start the system and troubleshoot standby coordinator issues while the system is available.

Options

-a Do not prompt the user for confirmation. Deactivates interactive mode.

-B parallel_processes The number of segments to start in parallel. If not specified, the utility will start up to 64 parallel processes depending on how many segment instances it needs to start.

-d coordinator_data_directory Optional. The coordinator host data directory. If not specified, the value set for `$COORDINATOR_DATA_DIRECTORY` will be used.

-l logfile_directory The directory to write the log file. Defaults to `~/gpAdminLogs`.

-m Optional. Starts the coordinator instance only, which may be useful for maintenance tasks. This mode only allows connections to the coordinator in utility mode. For example:

`PGOPTIONS='-c gp_role=utility' psql`

The consistency of the heap checksum setting on coordinator and segment instances is not checked.

-q Run in quiet mode. Command output is not displayed on the screen, but is still written to the log file.

-R Starts WarehousePG in restricted mode (only database superusers are allowed to connect).

--skip-heap-checksum-validation During startup, the utility does not validate the consistency of the heap checksum setting among the WarehousePG coordinator and segment instances. The default is to ensure that the heap checksum setting is the same on all instances, either enabled or deactivated.

```
> **Caution** Starting WarehousePG without this validation could lead to data loss. Use this option to start WarehousePG only when it is necessary to ignore the heap checksum verification errors to recover data or to troubleshoot the errors.
```

-t timeout_seconds Specifies a timeout in seconds to wait for a segment instance to start up. If a segment instance was shutdown abnormally (due to power failure or killing its `postgres` database listener process, for example), it may take longer to start up due to the database recovery and validation process. If not specified, the default timeout is 600 seconds.

-v Displays detailed status, progress and error messages output by the utility.

-y Optional. Do not start the standby coordinator host. The default is to start the standby coordinator host and synchronization process.

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-? | -h | --help Displays the online help.

--version Displays the version of this utility.

Examples

Start a WarehousePG cluster:

```
gpstart
```

Start a WarehousePG cluster in restricted mode (only allow superuser connections):

```
gpstart -R
```

Start the WarehousePG coordinator instance only and connect in utility mode:

```
gpstart -m
PGOPTIONS='-c gp_role=utility' psql
```

See Also

gpstop, gpinitsystem

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7.7.2.29 gpstate

Shows the status of a running WarehousePG cluster.

Synopsis

```
gpstate [-d <coordinator_data_directory>] [-B <parallel_processes>]
          [-s | -b | -Q \| -e\] \[-m \| -c] [-p] [-i] [-f] [-v | -q] | -x
          [-l <log_directory>]

gpstate -? | -h | --help
```

Description

The `gpstate` utility displays information about a running WarehousePG instance. There is additional information you may want to know about a WarehousePG cluster, since it is comprised of multiple PostgreSQL database instances (segments) spanning multiple machines. The `gpstate` utility provides additional status information for a WarehousePG cluster, such as:

- Which segments are down.
- Coordinator and segment configuration information (hosts, data directories, etc.).
- The ports used by the system.
- A mapping of primary segments to their corresponding mirror segments.

Options

-b (brief status) Optional. Display a brief summary of the state of the WarehousePG cluster. This is the default option.

-B parallel_processes The number of segments to check in parallel. If not specified, the utility will start up to 60 parallel processes depending on how many segment instances it needs to check.

-c (show primary to mirror mappings) Optional. Display mapping of primary segments to their corresponding mirror segments.

-d coordinator_data_directory Optional. The coordinator data directory. If not specified, the value set for `$COORDINATOR_DATA_DIRECTORY` will be used.

-e (show segments with mirror status issues) Show details on primary/mirror segment pairs that have potential issues. These issues include:

```
-   Whether any segments are down.
-   Whether any primary-mirror segment pairs are out of sync - including information on how many bytes are remaining to sync \(as displayed in the `WAL sync
remaining bytes` output field\).

    > **Note** `gpstate -e` does not display segment pairs that are in sync.


    > **Note** You must have `rsync` version 3.1.x or higher installed in order to view the tracking information for segments undergoing a differential recovery.

-   Whether any primary-mirror segment pairs are not in their preferred roles.
```

-f (show standby coordinator details) Display details of the standby coordinator host if configured.

-i (show WarehousePG version) Display the WarehousePG software version information for each instance.

-l logfile_directory The directory to write the log file. Defaults to `~/gpAdminLogs`.

-m (list mirrors) Optional. List the mirror segment instances in the system and their current role.

-p (show ports) List the port numbers used throughout the WarehousePG cluster.

-q (no screen output) Optional. Run in quiet mode. Except for warning messages, command output is not displayed on the screen. However, this information is still written to the log file.

-Q (quick status) Optional. Checks segment status in the system catalog on the coordinator host. Does not poll the segments for status.

-s (detailed status) Optional. Displays detailed status information about the WarehousePG cluster.

-v (verbose output) Optional. Displays error messages and outputs detailed status and progress information.

-x (expand) Optional. Displays detailed information about the progress and state of a WarehousePG cluster expansion.

-? | -h | --help (help) Displays the online help.

Output Field Definitions

The following output fields are reported by `gpstate -s` for the coordinator:

Output Data	Description
Coordinator host	host name of the coordinator
Coordinator postgres process ID	PID of the coordinator database listener process

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Output Data	Description
Coordinator data directory	file system location of the coordinator data directory
Coordinator port	port of the coordinator `postgres` database listener process
Coordinator current role	dispatch = regular operating mode utility = maintenance mode
WarehousePG cluster configuration type	Standard = one NIC per host Multi-Home = multiple NICs per host
WarehousePG initsystem version	version of WarehousePG when system was first initialized
WarehousePG current version	current version of WarehousePG
Postgres version	version of PostgreSQL that WarehousePG is based on
WarehousePG mirroring status	physical mirroring or none
Coordinator standby	host name of the standby coordinator
Standby coordinator state	status of the standby coordinator: active or passive

The following output fields are reported by `gpstate -s` for each primary segment:

Output Data	Description
Hostname	system-configured host name
Address	network address host name (NIC name)
Datadir	file system location of segment data directory
Port	port number of segment `postgres` database listener process
Current Role	current role of a segment: Mirror or Primary
Preferred Role	role at system initialization time: Mirror or Primary
Mirror Status	status of a primary/mirror segment pair: Synchronized = data is up to date on both Not in Sync = the mirror segment has not caught up to the primary segment
Current write location	Location where primary segment is writing new logs as they come in
Bytes remaining to send to mirror	Bytes remaining to be sent from primary to mirror
Active PID	active process ID of a segment
Coordinator reports status as	segment status as reported in the system catalog: Up or Down
Database status	status of WarehousePG to incoming requests: Up, Down, or Suspended. A Suspended state means database activity is temporarily paused while a segment transitions from one state to another.

The following output fields are reported by `gpstate -s` for each mirror segment:

Output Data	Description
Hostname	system-configured host name
Address	network address host name (NIC name)
Datadir	file system location of segment data directory
Port	port number of segment `postgres` database listener process
Current Role	current role of a segment: Mirror or Primary
Preferred Role	role at system initialization time: Mirror or Primary
Mirror Status	status of a primary/mirror segment pair: Synchronized = data is up to date on both Not in Sync = the mirror segment has not caught up to the primary segment
WAL Sent Location	Log location up to which the primary segment has sent log data to the mirror
WAL Flush Location	Log location up to which the mirror segment has flushed the log data to disk
WAL Replay Location	Log location up to which the mirror segment has replayed logs locally
Bytes received but remain to flush	Difference between flush log location and sent log location
Bytes received but remain to replay	Difference between replay log location and sent log location
Active PID	active process ID of a segment
Coordinator reports status as	segment status as reported in the system catalog: Up or Down
Database status	status of WarehousePG to incoming requests: Up, Down, or Suspended. A Suspended state means database activity is temporarily paused while a segment transitions from one state to another.

> **Note** When there is no connection between a primary segment and its mirror, `gpstate -s` displays `Unknown` in the following fields:

- `Bytes remaining to send to mirror`
- `WAL Sent Location`
- `WAL Flush Location`
- `WAL Replay Location`
- `Bytes received but remain to flush`
- `Bytes received but remain to replay`

The following output fields are reported by `gpstate -f` for standby coordinator replication status:

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Output Data	Description
Standby address	hostname of the standby coordinator
Standby data dir	file system location of the standby coordinator data directory
Standby port	port of the standby coordinator `postgres` database listener process
Standby PID	process ID of the standby coordinator
Standby status	status of the standby coordinator: Standby host passive
WAL Sender State	write-ahead log (WAL) streaming state: streaming, startup,backup, catchup
Sync state	WAL sender synchronization state: sync
Sent Location	WAL sender transaction log (xlog) record sent location
Flush Location	WAL receiver xlog record flush location
Replay Location	standby xlog record replay location

Examples

Show detailed status information of a WarehousePG cluster:

```
gpstate -s
```

Do a quick check for down segments in the coordinator host system catalog:

```
gpstate -Q
```

Show information about mirror segment instances:

```
gpstate -m
```

Show information about the standby coordinator configuration:

```
gpstate -f
```

Display the WarehousePG software version information:

```
gpstate -i
```

See Also

gpstart, gpexpandgplogfilter

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7.7.2.30 gpstop

Stops or restarts a WarehousePG cluster.

Synopsis

```
gpstop [-d <coordinator_data_directory>] [-B parallel_processes>]
       [-M smart | fast | immediate] [-t <timeout_seconds>] [-r] [-y] [-a]
       [-l <logfile_directory>] [-v | -q]

gpstop -m [-d <coordinator_data_directory>] [-y] [-l <logfile_directory>] [-v | -q]

gpstop -u [-d <coordinator_data_directory>] [-l <logfile_directory>] [-v | -q]

gpstop --host <host_namea> [-d <coordinator_data_directory>] [-l <logfile_directory>]
       [-t <timeout_seconds>] [-a] [-v | -q]

gpstop --version

gpstop -? | -h | --help
```

Description

The `gpstop` utility is used to stop the database servers that comprise a WarehousePG cluster. When you stop a WarehousePG cluster, you are actually stopping several `postgres` database server processes at once (the coordinator and all of the segment instances). The `gpstop` utility handles the shutdown of the individual instances. Each instance is shutdown in parallel.

The default shutdown mode (`-M smart`) waits for current client connections to finish before completing the shutdown. If any connections remain open after the timeout period, or if you interrupt with CTRL-C `gpstop` lists the open connections and prompts whether to continue waiting for connections to finish, or to perform a fast or immediate shutdown. The default timeout period is 120 seconds and can be changed with the `-t timeout\_seconds` option.

Specify the `-M fast` shutdown mode to roll back all in-progress transactions and terminate any connections before shutting down.

With the `-u` option, the utility uploads changes made to the coordinator `pg_hba.conf` file or to *runtime* configuration parameters in the coordinator `postgresql.conf` file without interruption of service. Note that any active sessions will not pick up the changes until they reconnect to the database.

Options

-a Do not prompt the user for confirmation.

-B parallel_processes The number of segments to stop in parallel. If not specified, the utility will start up to 64 parallel processes depending on how many segment instances it needs to stop.

-d coordinator_data_directory Optional. The coordinator host data directory. If not specified, the value set for `$COORDINATOR_DATA_DIRECTORY` will be used.

--host host_name The utility shuts down the WarehousePG segment instances on the specified host to allow maintenance on the host. Each primary segment instance on the host is shut down and the associated mirror segment instance is promoted to a primary segment if the mirror segment is on another host. Mirror segment instances on the host are shut down.

The segment instances are not shut down and the utility returns an error in these cases:

```
-   Segment mirroring is not enabled for the system.
-   The coordinator or standby coordinator is on the host.
-   Both a primary segment instance and its mirror are on the host.
```

This option cannot be specified with the `-m` , `-r` , `-u` , or `-y` options.

```
> **Note** The `gprecoverseg` utility restores segment instances. Run `gprecoverseg` commands to start the segments as mirrors and then to return the segments to
their preferred role \(primary segments\).
```

-l logfile_directory The directory to write the log file. Defaults to `~/gpAdminLogs` .

-m Optional. Shuts down a WarehousePG coordinator instance that was started in maintenance mode.

-M fast Fast shut down. Any transactions in progress are interrupted and rolled back.

-M immediate Immediate shut down. Any transactions in progress are cancelled.

This mode kills all `postgres` processes without allowing the database server to complete transaction processing or clean up any temporary or in-process work files.

-M smart Smart shut down. This is the default shutdown mode. `gpstop` waits for active user connections to disconnect and then proceeds with the shutdown. If any user connections remain open after the timeout period (or if you interrupt by pressing CTRL-C) `gpstop` lists the open user connections and prompts whether to continue waiting for connections to finish, or to perform a fast or immediate shutdown.

-q Run in quiet mode. Command output is not displayed on the screen, but is still written to the log file.

-r Restart after shutdown is complete.

-t timeout_seconds Specifies a timeout threshold (in seconds) to wait for a segment instance to shutdown. If a segment instance does not shutdown in the specified number of seconds, `gpstop` displays a message indicating that one or more segments are still in the process of shutting down and that you cannot restart WarehousePG until the segment instance(s) are stopped. This option is useful in situations where `gpstop` is run and there are very large transactions that need to rollback. These large transactions can take over a minute to rollback and surpass the default timeout period of 120 seconds.

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-u This option reloads the `pg_hba.conf` files of the coordinator and segments and the runtime parameters of the `postgresql.conf` files but does not shutdown the WarehousePG cluster. Use this option to make new configuration settings active after editing `postgresql.conf` or `pg_hba.conf`. Note that this only applies to configuration parameters that are designated as *runtime* parameters.

-v Displays detailed status, progress and error messages output by the utility.

-y Do not stop the standby coordinator process. The default is to stop the standby coordinator.

-? | -h | --help Displays the online help.

--version Displays the version of this utility.

Examples

Stop a WarehousePG cluster in smart mode:

```
gpstop
```

Stop a WarehousePG cluster in fast mode:

```
gpstop -M fast
```

Stop all segment instances and then restart the system:

```
gpstop -r
```

Stop a coordinator instance that was started in maintenance mode:

```
gpstop -m
```

Reload the `postgresql.conf` and `pg_hba.conf` files after making configuration changes but do not shutdown the WarehousePG cluster:

```
gpstop -u
```

See Also

gpstart

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7.7.2.31 gpsync

Copies files between multiple hosts at once.

Synopsis

```
gpsync { -f <hostfile_gpssh> | -h <hostname> [-h <hostname> ...] }
      [-a][-J <character>] [-v] [[<user>@]<hostname>:]<file_to_copy> [...]
      [[<user>@]<hostname>:]<copy_to_path>

gpsync -?

gpsync --version
```

Description

The `gpsync` utility allows you to copy one or more files from the specified hosts to other specified hosts in one command using remote sync. For example, you can copy a file from the WarehousePG coordinator host to all of the segment hosts at the same time.

To specify the hosts involved in the remote sync session, use the `-f` option to specify a file containing a list of host names, or use the `-h` option to name single host names on the command-line. At least one host name (`-h`) or a host file (`-f`) is required. The `-J` option allows you to specify a single character to substitute for the hostname in the `copy from` and `copy to` destination strings. If `-J` is not specified, the default substitution character is an equal sign (`=`). For example, the following command will copy `.bashrc` from the local host to `/home/gpadmin` on all hosts named in `hostfile_gpssh` :

```
gpsync -f hostfile_gpssh .bashrc =:/home/gpadmin
```

If a user name is not specified in the host list or with user `@` in the file path, `gpsync` will copy files as the currently logged in user. To determine the currently logged in user, do a `whoami` command. By default, `gpsync` goes to `$HOME` of the session user on the remote hosts after login. To ensure the file is copied to the correct location on the remote hosts, it is recommended that you use absolute paths.

Before using `gpsync` , you must have a trusted host setup between the hosts involved in the remote sync session. You can use the utility `gpssh-exkeys` to update the known host files and exchange public keys between hosts if you have not done so already.

Options

-f hostfile_gpssh Specifies the name of a file that contains a list of hosts that will participate in this remote sync session. The syntax of the host file is one host per line as follows:

```
<hostname>
```

-h hostname

Specifies a single host name that will participate in this remote sync session. You can use the `-h` option multiple times to specify multiple host names.

-a

Sync source and target directories in archival mode.

-J character

The `-J` option allows you to specify a single character to substitute for the hostname in the `copy from` and `copy to` destination strings. If `-J` is not specified, the default substitution character is an equal sign (`=`).

-v (verbose mode)

Optional. Reports additional messages in addition to the remote sync command output.

file_to_copy

Required. The file name (or absolute path) of a file that you want to copy to other hosts (or file locations). This can be either a file on the local host or on another named host.

copy_to_path

Required. The path where you want the file(s) to be copied on the named hosts. If an absolute path is not used, the file will be copied relative to `$HOME` of the session user. You can also use the equal sign ' `=` ' (or another character that you specify with the `-J` option) in place of a hostname. This will then substitute in each host name as specified in the supplied host file (`-f`) or with the `-h` option.

-? (help)

Displays the online help.

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--version

Displays the version of this utility.

Examples

Copy the file named `installer.tar` to `/` on all the hosts in the file `hostfile_gpssh`.

```
gpsync -f hostfile_gpssh installer.tar =:/
```

Copy the file named myfuncs.so to the specified location on the hosts named `sdw1` and `sdw2`:

```
gpsync -h sdw1 -h sdw2 myfuncs.so =:/usr/edb/whpg7/lib
```

See Also

gpssh, gpssh-exkeys

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7.7.2.32 pg_config

Retrieves information about the installed version of WarehousePG.

Synopsis

```
pg_config [<option> ...]

pg_config -? | --help

pg_config --gp_version
```

Description

The `pg_config` utility prints configuration parameters of the currently installed version of WarehousePG. It is intended, for example, to be used by software packages that want to interface to WarehousePG to facilitate finding the required header files and libraries. Note that information printed out by `pg_config` is for the WarehousePG coordinator only.

If more than one option is given, the information is printed in that order, one item per line. If no options are given, all available information is printed, with labels.

Options

--bindir Print the location of user executables. Use this, for example, to find the `psql` program. This is normally also the location where the `pg_config` program resides.

--docdir Print the location of documentation files.

--includedir Print the location of C header files of the client interfaces.

--pkgincludedir Print the location of other C header files.

--includedir-server Print the location of C header files for server programming.

--libdir Print the location of object code libraries.

--pkglibdir Print the location of dynamically loadable modules, or where the server would search for them. (Other architecture-dependent data files may also be installed in this directory.)

--localedir Print the location of locale support files.

--mandir Print the location of manual pages.

--sharedir Print the location of architecture-independent support files.

--sysconfdir Print the location of system-wide configuration files.

--pgxs Print the location of extension makefiles.

--configure Print the options that were given to the configure script when WarehousePG was configured for building.

--cc Print the value of the CC variable that was used for building WarehousePG. This shows the C compiler used.

--cppflags Print the value of the `CPPFLAGS` variable that was used for building WarehousePG. This shows C compiler switches needed at preprocessing time.

--cflags Print the value of the `CFLAGS` variable that was used for building WarehousePG. This shows C compiler switches.

--cflags_sl Print the value of the `CFLAGS_SL` variable that was used for building WarehousePG. This shows extra C compiler switches used for building shared libraries.

--ldflags Print the value of the `LDFLAGS` variable that was used for building WarehousePG. This shows linker switches.

--ldflags_ex Print the value of the `LDFLAGS_EX` variable that was used for building WarehousePG. This shows linker switches that were used for building executables only.

--ldflags_sl Print the value of the `LDFLAGS_SL` variable that was used for building WarehousePG. This shows linker switches used for building shared libraries only.

--libs Print the value of the `LIBS` variable that was used for building WarehousePG. This normally contains `-l` switches for external libraries linked into WarehousePG.

--version Print the version of PostgreSQL backend server.

--gp_version Print the version of WarehousePG.

Examples

To reproduce the build configuration of the current WarehousePG installation, run the following command:

```
eval ./configure 'pg_config --configure'
```

The output of `pg_config --configure` contains shell quotation marks so arguments with spaces are represented correctly. Therefore, using `eval` is required for proper results.

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7.7.2.33 pg_dump

Extracts a database into a single script file or other archive file.

Synopsis

```
pg_dump [<connection-option> ...] [<dump_option> ...] [<dbname>]

pg_dump -? | --help

pg_dump -V | --version
```

Description

`pg_dump` is a standard PostgreSQL utility for backing up a database, and is also supported in WarehousePG. It creates a single (non-parallel) dump file. For routine backups of WarehousePG, it is better to use the WarehousePG backup utility, `gpbackup`, for the best performance.

Use `pg_dump` if you are migrating your data to another database vendor's system, or to another WarehousePG cluster with a different segment configuration (for example, if the system you are migrating to has greater or fewer segment instances). To restore, you must use the corresponding pg_restore utility (if the dump file is in archive format), or you can use a client program such aspsql (if the dump file is in plain text format).

Since `pg_dump` is compatible with regular PostgreSQL, it can be used to migrate data into WarehousePG. The `pg_dump` utility in WarehousePG is very similar to the PostgreSQL `pg_dump` utility, with the following exceptions and limitations:

- If using `pg_dump` to backup a WarehousePG database, keep in mind that the dump operation can take a long time (several hours) for very large databases. Also, you must make sure you have sufficient disk space to create the dump file.
- If you are migrating data from one WarehousePG cluster to another, use the `--gp-syntax` command-line option to include the `DISTRIBUTED BY` clause in `CREATE TABLE` statements. This ensures that WarehousePG table data is distributed with the correct distribution key columns upon restore.

`pg_dump` makes consistent backups even if the database is being used concurrently. `pg_dump` does not block other users accessing the database (readers or writers).

When used with one of the archive file formats and combined with `pg_restore`, `pg_dump` provides a flexible archival and transfer mechanism. `pg_dump` can be used to backup an entire database, then `pg_restore` can be used to examine the archive and/or select which parts of the database are to be restored. The most flexible output file formats are the custom format (`-Fc`) and the directory format (`-Fd`). They allow for selection and reordering of all archived items, support parallel restoration, and are compressed by default. The directory format is the only format that supports parallel dumps.

Options

\<dbname> Specifies the name of the database to be dumped. If this is not specified, the environment variable `PGDATABASE` is used. If that is not set, the user name specified for the connection is used.

Dump Options

-a | --data-only Dump only the data, not the schema (data definitions). Table data and sequence values are dumped.

This option is similar to, but for historical reasons not identical to, specifying `--section=data`.

-b | --blobs Include large objects in the dump. This is the default behavior except when `--schema`, `--table`, or `--schema-only` is specified. The `-b` switch is only useful add large objects to dumps where a specific schema or table has been requested. Note that blobs are considered data and therefore will be included when `--data-only` is used, but not when `--schema-only` is.

```
> **Note** WarehousePG does not support the PostgreSQL [large object facility](https://www.postgresql.org/docs/12/largeobjects.html) for streaming user data that is stored in large-object structures.
```

-B | --no-blobs Exclude large objects in the dump.

When both `-b` and `-B` are specified, `pg_dump` outputs large objects, when data is being dumped, see the `-b` documentation.

```
> **Note** WarehousePG does not support the PostgreSQL [large object facility](https://www.postgresql.org/docs/12/largeobjects.html) for streaming user data that is stored in large-object structures.
```

-c | --clean Adds commands to the text output file to clean (drop) database objects prior to outputting the commands for creating them. (Restore might generate some harmless error messages, if any objects were not present in the destination database.) Note that objects are not dropped before the dump operation begins, but `DROP` commands are added to the DDL dump output files so that when you use those files to do a restore, the `DROP` commands are run prior to the `CREATE` commands. This option is only meaningful for the plain-text format. For the archive formats, you may specify the option when you callpg_restore.

-C | --create Begin the output with a command to create the database itself and reconnect to the created database. (With a script of this form, it doesn't matter which database in the destination installation you connect to before running the script.) If `--clean` is also specified, the script drops and recreates the target database before reconnecting to it. This option is only meaningful for the plain-text format. For the archive formats, you may specify the option when you call pg_restore. With `--create`, the output also includes the database's comment if any, and any configuration variable settings that are specific to this database, that is, any `ALTER DATABASE ... SET ...` and `ALTER ROLE ... IN DATABASE ... SET ...` commands that mention this database. Access privileges for the database itself are also dumped, unless `--no-acl` is specified.

-E \<encoding> | --encoding=\<encoding> Create the dump in the specified character set encoding. By default, the dump is created in the database encoding. (Another way to get the same result is to set the `PGCLIENTENCODING` environment variable to the desired dump encoding.)

-f \<file> | --file=\<file> Send output to the specified file. This parameter can be omitted for file-based output formats, in which case the standard output is used. It must be given for the directory output format however, where it specifies the target directory instead of a file. In this case the directory is created by `pg_dump` and must not exist before.

-F p|c|d|t | --format=plain|custom|directory|tar Selects the format of the output. format can be one of the following:

- p | plain — Output a plain-text SQL script file (the default).
- c | custom — Output a custom archive suitable for input into pg_restore. Together with the directory output format, this is the most flexible output format in that it allows manual selection and reordering of archived items during restore. This format is compressed by default.

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- d | directory — Output a directory-format archive suitable for input into `pg_restore`. This will create a directory with one file for each table and blob being dumped, plus a so-called Table of Contents file describing the dumped objects in a machine-readable format that `pg_restore` can read. A directory format archive can be manipulated with standard Unix tools; for example, files in an uncompressed archive can be compressed with the `gzip` tool. This format is compressed by default and also supports parallel dumps.
- t | tar — Output a tar-format archive suitable for input into pg_restore. The tar format is compatible with the directory format; extracting a tar-format archive produces a valid directory-format archive. However, the tar format does not support compression. Also, when using tar format the relative order of table data items cannot be changed during restore.

-j \<njobs> | --jobs=\<njobs> Run the dump in parallel by dumping \<njobs> tables simultaneously. This option reduces the time of the dump but it also increases the load on the database server. You can only use this option with the directory output format because this is the only output format where multiple processes can write their data at the same time.

> **Note** Parallel dumps using `pg_dump` are parallelized only on the query dispatcher (coordinator) node, not across the query executor (segment) nodes as is the case when you use `gpbackup`.

`pg_dump` will open \<njobs> + 1 connections to the database, so make sure your max_connections setting is high enough to accommodate all connections.

Requesting exclusive locks on database objects while running a parallel dump could cause the dump to fail. The reason is that the `pg_dump` coordinator process requests shared locks on the objects that the worker processes are going to dump later in order to make sure that nobody deletes them and makes them go away while the dump is running. If another client then requests an exclusive lock on a table, that lock will not be granted but will be queued waiting for the shared lock of the coordinator process to be released. Consequently, any other access to the table will not be granted either and will queue after the exclusive lock request. This includes the worker process trying to dump the table. Without any precautions this would be a classic deadlock situation. To detect this conflict, the `pg_dump` worker process requests another shared lock using the `NOWAIT` option. If the worker process is not granted this shared lock, somebody else must have requested an exclusive lock in the meantime and there is no way to continue with the dump, so `pg_dump` has no choice but to cancel the dump.

For a consistent backup, the database server needs to support synchronized snapshots, a feature that was introduced in WarehousePG 6.0. With this feature, database clients can ensure they see the same data set even though they use different connections. `pg_dump -j` uses multiple database connections; it connects to the database once with the coordinator process and once again for each worker job. Without the synchronized snapshot feature, the different worker jobs wouldn't be guaranteed to see the same data in each connection, which could lead to an inconsistent backup.

If you want to run a parallel dump of a pre-6.0 server, you need to make sure that the database content doesn't change from between the time the coordinator connects to the database until the last worker job has connected to the database. The easiest way to do this is to halt any data modifying processes (DDL and DML) accessing the database before starting the backup. You also need to specify the `--no-synchronized-snapshots` parameter when running `pg_dump -j` against a pre-6.0 WarehousePG server.

-n \<pattern> | --schema=\<pattern> Dump only schemas matching the schema pattern; this selects both the schema itself, and all its contained objects. When this option is not specified, all non-system schemas in the target database will be dumped. Multiple schemas can be selected by writing multiple `-n` switches. Also, the pattern parameter is interpreted as a pattern according to the same rules used by `psql`'s `\d` commands, so multiple schemas can also be selected by writing wildcard characters in the pattern. When using wildcards, be careful to quote the pattern if needed to prevent the shell from expanding the wildcards.

When `-n` is specified, `pg_dump` makes no attempt to dump any other database objects that the selected schema(s) may depend upon. Therefore, there is no guarantee that the results of a specific-schema dump can be successfully restored by themselves into a clean database.

```
> **Note** Non-schema objects such as blobs are not dumped when `-n` is specified. You can add blobs back to the dump with the `--blobs` switch.
```

-N \<pattern> | --exclude-schema=\<pattern> Do not dump any schemas matching the pattern. The pattern is interpreted according to the same rules as for `-n`. `-N` can be specified more than once to exclude schemas matching any of several patterns. When both `-n` and `-N` are specified, the behavior is to dump just the schemas that match at least one `-n` switch but no `-N` switches. If `-N` appears without `-n`, then schemas matching `-N` are excluded from what is otherwise a normal dump.

-O | --no-owner Do not output commands to set ownership of objects to match the original database. By default, `pg_dump` issues `ALTER OWNER` or `SET SESSION AUTHORIZATION` statements to set ownership of created database objects. These statements will fail when the script is run unless it is started by a superuser (or the same user that owns all of the objects in the script). To make a script that can be restored by any user, but will give that user ownership of all the objects, specify `-O`. This option is only meaningful for the plain-text format. For the archive formats, you may specify the option when you callpg_restore.

-s | --schema-only Dump only the object definitions (schema), not data.

This option is the inverse of `--data-only`. It is similar to, but for historical reasons not identical to, specifying `--section=pre-data --section=post-data`.

(Do not confuse this with the `--schema` option, which uses the word "schema" in a different meaning.)

To exclude table data for only a subset of tables in the database, see `--exclude-table-data`.

-S \<username> | --superuser=\<username> Specify the superuser user name to use when deactivating triggers. This is relevant only if `--disable-triggers` is used. It is better to leave this out, and instead start the resulting script as a superuser.

```
> **Note** WarehousePG does not support user-defined triggers.
```

-t \<pattern> | --table=\<pattern> Dump only tables (or views or materialized views or sequences or foreign tables) matching the pattern. Specify the table in the format `schema.table`.

Multiple tables can be selected by writing multiple `-t` switches. Also, the pattern parameter is interpreted as a pattern according to the same rules used by `psql`'s `\d` commands, so multiple tables can also be selected by writing wildcard characters in the pattern. When using wildcards, be careful to quote the pattern if needed to prevent the shell from expanding the wildcards. The `-n` and `-N` switches have no effect when `-t` is used, because tables selected by `-t` will be dumped regardless of those switches, and non-table objects will not be dumped.

```
> **Note** When `-t` is specified, `pg_dump` makes no attempt to dump any other database objects that the selected table\(s\) may depend upon. Therefore, there is
no guarantee that the results of a specific-table dump can be successfully restored by themselves into a clean database.

Also, `-t` cannot be used to specify a child table of a partitioned table. To dump a partitioned table, you must specify the root partitioned table name.
```

-T \<pattern> | --exclude-table=\<pattern> Do not dump any tables matching the table pattern. The pattern is interpreted according to the same rules as for `-t`. `-T` can be specified more than once to exclude tables matching any of several patterns. When both `-t` and `-T` are given, the behavior is to dump just the tables that match at least one `-t` switch but no `-T` switches. If `-T` appears without `-t`, then tables matching `-T` are excluded from what is otherwise a normal dump.

-v | --verbose Specifies verbose mode. This will cause `pg_dump` to output detailed object comments and start/stop times to the dump file, and progress messages to standard error.

-V | --version Print the `pg_dump` version and exit.

-x | --no-privileges | --no-acl Prevent dumping of access privileges (`GRANT/REVOKE` commands).

-Z 0..9 | --compress=0..9 Specify the compression level to use. Zero means no compression. For the custom archive format, this specifies compression of individual table-data segments, and the default is to compress at a moderate level.

For plain text output, setting a non-zero compression level causes the entire output file to be compressed, as though it had been fed through `gzip`; but the default is not to compress. The tar archive format currently does not support compression at all.

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--binary-upgrade This option is for use by in-place upgrade utilities. Its use for other purposes is not recommended or supported. The behavior of the option may change in future releases without notice.

--column-inserts | --attribute-inserts Dump data as `INSERT` commands with explicit column names `(INSERT INTO <table> (<column>, ...) VALUES ...)`. This will make restoration very slow; it is mainly useful for making dumps that can be loaded into non-PostgreSQL-based databases. However, since this option generates a separate command for each row, an error in reloading a row causes only that row to be lost rather than the entire table contents.

--disable-dollar-quoting This option deactivates the use of dollar quoting for function bodies, and forces them to be quoted using SQL standard string syntax.

--disable-triggers This option is relevant only when creating a data-only dump. It instructs `pg_dump` to include commands to temporarily deactivate triggers on the target tables while the data is reloaded. Use this if you have triggers on the tables that you do not want to invoke during data reload. The commands emitted for `--disable-triggers` must be done as superuser. So, you should also specify a superuser name with `-S`, or preferably be careful to start the resulting script as a superuser. This option is only meaningful for the plain-text format. For the archive formats, you may specify the option when you call pg_restore.

```
> **Note** WarehousePG does not support user-defined triggers.
```

--enable-row-security This option is relevant only when dumping the contents of a table which has row security. By default, `pg_dump` sets `row_security` to off, to ensure that all data is dumped from the table. If the user does not have sufficient privileges to bypass row security, then an error is thrown. This parameter instructs `pg_dump` to set `row_security` to on instead, allowing the user to dump the parts of the contents of the table that they have access to.

If you use this option, you likely also want the dump be in `INSERT` format, as the `COPY FROM` during restore does not support row security.

--exclude-table-and-children=\<pattern> This option is equivalent to `-T` or `--exclude-table`, except that it also excludes any partitions of child tables that inherit from the table(s) matching the \<table> name.

--exclude-table-data=\<pattern> Do not dump data for any tables matching the pattern. The pattern is interpreted according to the same rules as for `-t`. `--exclude-table-data` can be specified more than once to exclude tables matching any of several patterns. This option is useful when you need the definition of a particular table even though you do not need the data in it.

To exclude data for all tables in the database, see `--schema-only`.

--exclude-table-data-and-children=\<pattern> This option is equivalent to `--exclude-table-data`, except that it also excludes any partitions of child tables that inherit from the table(s) matching the \<table> name.

--extra-float-digits=ndigits Use the specified value of `extra_float_digits` when dumping floating-point data, instead of the maximum available precision. Routine dumps made for backup purposes should not use this option.

--if-exists Use conditional commands (for example, add an `IF EXISTS` clause) when cleaning database objects. This option is not valid unless `--clean` is also specified.

--inserts Dump data as `INSERT` commands (rather than `COPY`). This will make restoration very slow; it is mainly useful for making dumps that can be loaded into non-PostgreSQL-based databases. However, since this option generates a separate command for each row, an error in reloading a row causes only that row to be lost rather than the entire table contents. Note that the restore may fail altogether if you have rearranged column order. The `--column-inserts` option is safe against column order changes, though even slower.

--load-via-partition-root When dumping data for a table partition, make the `COPY` or `INSERT` statements target the root of the partitioning hierarchy that contains it, rather than the partition itself. This causes the appropriate partition to be re-determined for each row when the data is loaded. This may be useful when restoring data on a server where rows do not always fall into the same partitions as they did on the original server. That could happen, for example, if the partitioning column is of type `text` and the two systems have different definitions of the collation used to sort the partitioning column.

--lock-wait-timeout=\<timeout> Do not wait forever to acquire shared table locks at the beginning of the dump. Instead, fail if unable to lock a table within the specified timeout. The timeout may be specified in any of the formats accepted by `SET statement_timeout`. Specify timeout as a number of milliseconds.

--no-comments Do not dump comments.

--no-security-labels Do not dump security labels.

--no-sync By default, `pg_dump` waits for all files to be written safely to disk. This option causes `pg_dump` to return without waiting, which is faster, but could leave the dump corrupt if there is a subsequent operating system crash. This option is generally useful for testing but should not be used when dumping data from a production installation.

--no-synchronized-snapshots This option allows running `pg_dump -j` against a pre-6.0 WarehousePG server; see the documentation of the `-j` parameter for more details.

--no-tablespaces Do not output commands to select tablespaces. With this option, all objects will be created in whichever tablespace is the default during restore.

This option is only meaningful for the plain-text format. For the archive formats, you can specify the option when you call `pg_restore`.

--no-unlogged-table-data Do not dump the contents of unlogged tables. This option has no effect on whether or not the table definitions (schema) are dumped; it only suppresses dumping the table data. Data in unlogged tables is always excluded when dumping from a standby server.

--on-conflict-do-nothing Add `ON CONFLICT DO NOTHING` to `INSERT` commands. This option is not valid unless `--inserts`, `--column-inserts`, or `--rows-per-insert` is also specified.

--quote-all-identifiers Force quoting of all identifiers. This option is recommended when dumping a database from a server whose WarehousePG major version is different from `pg_dump`'s, or when the output is intended to be loaded into a server of a different major version. By default, `pg_dump` quotes only identifiers that are reserved words in its own major version. This sometimes results in compatibility issues when dealing with servers of other versions that may have slightly different sets of reserved words. Using `--quote-all-identifiers` prevents such issues, at the price of a harder-to-read dump script.

--rows-per-insert=\<nrows> Dump data as `INSERT` commands (rather than `COPY`). Controls the maximum number of rows per `INSERT` command. The value specified must be a number greater than zero. Any error during restoring will cause only rows that are part of the problematic `INSERT` to be lost, rather than the entire table contents.

--section=\<sectionname> Only dump the named section. The section name can be `pre-data`, `data`, or `post-data`. This option can be specified more than once to select multiple sections. The default is to dump all sections.

The `data` section contains actual table data and sequence values. `post-data` items include definitions of indexes, triggers, rules, and constraints other than validated check constraints. `pre-data` items include all other data definition items.

--serializable-deferrable Use a serializable transaction for the dump, to ensure that the snapshot used is consistent with later database states; but do this by waiting for a point in the transaction stream at which no anomalies can be present, so that there isn't a risk of the dump failing or causing other transactions to roll back with a `serialization_failure`.

This option is not beneficial for a dump which is intended only for disaster recovery. It could be useful for a dump used to load a copy of the database for reporting or other read-only load sharing while the original database continues to be updated. Without it the dump may reflect a state which is not consistent with any serial execution of the transactions eventually committed. For example, if batch processing techniques are used, a batch may show as closed in the dump without all of the items which are in the batch appearing.

This option will make no difference if there are no read-write transactions active when `pg_dump` is started. If read-write transactions are active, the start of the dump may be delayed for an indeterminate length of time. Once running, performance with or without the switch is the same.

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> **Note** Because WarehousePG does not support serializable transactions, the `--serializable-deferrable` option has no effect in WarehousePG.

--snapshot=\<snapshotname> Use the specified synchronized snapshot when making a dump of the database.

This option is useful when you need to synchronize the dump with a concurrent session.

In the case of a parallel dump, the snapshot name defined by this option is used rather than taking a new snapshot.

--strict-names Require that each schema (`-n` / `--schema`) and table (`-t` / `--table`) qualifier match at least one schema/table in the database to be dumped. Note that if none of the schema/table qualifiers find matches, `pg_dump` generates an error even without `--strict-names` .

This option has no effect on `-N` / `--exclude-schema` , `-T` / `--exclude-table` , or `--exclude-table-data` . An exclude pattern failing to match any objects is not considered an error.

--table-and-children=\<table> This option is equivalent to `-t` or `--table` , except that it also includes any partitions of child tables that inherit from the table(s) matching the \<table> name.

--use-set-session-authorization Output SQL-standard `SET SESSION AUTHORIZATION` commands instead of `ALTER OWNER` commands to determine object ownership. This makes the dump more standards-compatible, but depending on the history of the objects in the dump, may not restore properly. A dump using `SET SESSION AUTHORIZATION` requires superuser privileges to restore correctly, whereas `ALTER OWNER` requires lesser privileges.

--gp-syntax | --no-gp-syntax Use `--gp-syntax` to dump WarehousePG syntax in the `CREATE TABLE` statements. This allows the distribution policy (`DISTRIBUTED BY` or `DISTRIBUTED RANDOMLY` clauses) of a WarehousePG table to be dumped, which is useful for restoring into other WarehousePG clusters. The default is to include WarehousePG syntax when connected to a WarehousePG cluster, and to exclude it when connected to a regular PostgreSQL system.

--function-oids \<oids> Dump the function(s) specified in the oids list of object identifiers.

```
> **Note** This option is provided solely for use by other administration utilities; its use for any other purpose is not recommended or supported. The behavior
of the option may change in future releases without notice.
```

--relation-oids \<oids> Dump the relation(s) specified in the oids list of object identifiers.

```
> **Note** This option is provided solely for use by other administration utilities; its use for any other purpose is not recommended or supported. The behavior
of the option may change in future releases without notice.
```

-? | --help Show help about `pg_dump` command line arguments, and exit.

Connection Options

-d \<dbname> | --dbname=\<dbname> Specifies the name of the database to connect to. This is equivalent to specifying dbname as the first non-option argument on the command line.

If this parameter contains an `=` sign or starts with a valid URI prefix (`postgresql://` or `postgres://`), it is treated as a conninfo string. See Connection Strings in the PostgreSQL documentation for more information. Connection strings parameters override any conflicting command line option.

-h \<host> | --host=\<host> The host name of the machine on which the WarehousePG coordinator database server is running. If not specified, reads from the environment variable `PGHOST` or defaults to `localhost` .

-p \<port> | --port=\<port> The TCP port on which the WarehousePG coordinator database server is listening for connections. If not specified, reads from the environment variable `PGPORT` or defaults to `5432` . `

-U \<username> | --username=\<username> The database role name to connect as. If not specified, reads from the environment variable `PGUSER` or defaults to the current system role name.

-W | --password Force a password prompt.

This option is never required; `pg_dump` automatically prompts for a password if the server demands password authentication. However, `pg_dump` will waste a connection attempt determining that the server wants a password. In some cases it is worth typing `-W` to avoid the extra connection attempt.

-w | --no-password Never issue a password prompt. If the server requires password authentication and a password is not available by other means such as a `.pgpass` file, the connection attempt will fail. This option can be useful in batch jobs and scripts where no user is present to enter a password.

--role=\<rolename> Specifies a role name to be used to create the dump. This option causes `pg_dump` to issue a `SET ROLE <rolename>` command after connecting to the database. It is useful when the authenticated user (specified by `-U`) lacks privileges needed by `pg_dump` , but can switch to a role with the required rights. Some installations have a policy against logging in directly as a superuser, and use of this option allows dumps to be made without violating the policy.

Environment

PGDATABASE PGHOST PGOPTIONS PGPORT PGUSER Default connection parameters.

PG_COLOR Specifies whether to use color in diagnostic messages. Possible values are `always` , `auto` , and `never` .

This utility also uses the environment variables supported by libpq.

Notes

If your database cluster has any local additions to the `template1` database, be careful to restore the output of `pg_dump` into a truly empty database; otherwise you are likely to get errors due to duplicate definitions of the added objects. To make an empty database without any local additions, copy from `template0` not `template1` , for example:

```
CREATE DATABASE foo WITH TEMPLATE template0;
```

When a data-only dump is chosen and the option `--disable-triggers` is used, `pg_dump` emits commands to deactivate triggers on user tables before inserting the data and commands to re-enable them after the data has been inserted. If the restore is stopped in the middle, the system catalogs may be left in the wrong state.

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The dump file produced by `pg_dump` does not contain the statistics used by the optimizer to make query planning decisions. Therefore, it is wise to run `ANALYZE` after restoring from a dump file to ensure optimal performance.

The database activity of `pg_dump` is normally collected by the statistics collector. If this is undesirable, you can set parameter `track_counts` to false via `PGOPTIONS` or the `ALTER USER` command.

Because `pg_dump` may be used to transfer data to newer versions of WarehousePG, the output of `pg_dump` can be expected to load into WarehousePG versions newer than `pg_dump` 's version. `pg_dump` can also dump from WarehousePG versions older than its own version. However, `pg_dump` cannot dump from WarehousePG versions newer than its own major version; it will refuse to even try, rather than risk making an invalid dump. Also, it is not guaranteed that `pg_dump` 's output can be loaded into a server of an older major version — not even if the dump was taken from a server of that version. Loading a dump file into an older server may require manual editing of the dump file to remove syntax not understood by the older server. Use of the `--quote-all-identifiers` option is recommended in cross-version cases, as it can prevent problems arising from varying reserved-word lists in different WarehousePG versions.

Examples

Dump a database called `mydb` into a SQL-script file:

```
pg_dump mydb > db.sql
```

To reload such a script into a (freshly created) database named `newdb` :

```
psql -d newdb -f db.sql
```

Dump a WarehousePG in tar file format and include distribution policy information:

```
pg_dump -Ft --gp-syntax mydb > db.tar
```

To dump a database into a custom-format archive file:

```
pg_dump -Fc mydb > db.dump
```

To dump a database into a directory-format archive:

```
pg_dump -Fd mydb -f dumpdir
```

To dump a database into a directory-format archive in parallel with 5 worker jobs:

```
pg_dump -Fd mydb -j 5 -f dumpdir
```

To reload an archive file into a (freshly created) database named `newdb` :

```
pg_restore -d newdb db.dump
```

To reload an archive file into the same database it was dumped from, discarding the current contents of that database:

```
pg_restore -d postgres --clean --create db.dump
```

To dump a single table named `mytab` :

```
pg_dump -t mytab mydb > db.sql
```

To dump all tables whose names start with `emp` in the `detroit` schema, except for the table named `employee_log` :

```
pg_dump -t 'detroit.emp*' -T detroit.employee_log mydb > db.sql
```

To dump all schemas whose names start with `east` or `west` and end in `gsm` , excluding any schemas whose names contain the word `test` :

```
pg_dump -n 'east*gsm' -n 'west*gsm' -N '*test*' mydb > db.sql
```

The same dump as above, using regular expression notation to consolidate the switches:

```
pg_dump -n '(east|west)*gsm' -N '*test*' mydb > db.sql
```

To dump all database objects except for tables whose names begin with `ts_` :

```
pg_dump -T 'ts_*' mydb > db.sql
```

To specify an upper-case or mixed-case name in `-t` and related switches, you need to double-quote the name; else it will be folded to lower case. But double quotes are special to the shell, so they in turn must be quoted. To dump a single table with a mixed-case name, you must specify something like:

```
pg_dump -t "\"MixedCaseName\"" mydb > mytab.sql
```

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See Also

pg_dumpall, pg_restore, psql

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7.7.2.34 pg_dumpall

Extracts all databases in a WarehousePG cluster to a single script file or other archive file.

Synopsis

```
pg_dumpall [<connection-option> ...] [<dump_option> ...]

pg_dumpall -? | --help

pg_dumpall -V | --version
```

Description

`pg_dumpall` is a standard PostgreSQL utility for backing up all databases in a WarehousePG (or PostgreSQL) instance, and is also supported in WarehousePG. It creates a single (non-parallel) dump file. For routine backups of WarehousePG it is better to use the WarehousePG backup utility, `gpbackup`, for the best performance.

`pg_dumpall` creates a single script file that contains SQL commands that can be used as input to psql to restore the databases. It does this by calling pg_dump for each database. `pg_dumpall` also dumps global objects that are common to all databases. (`pg_dump` does not save these objects.) This currently includes information about database users and groups, and access permissions that apply to databases as a whole.

Since `pg_dumpall` reads tables from all databases you will most likely have to connect as a database superuser in order to produce a complete dump. Also you will need superuser privileges to run the saved script in order to be allowed to add users and groups, and to create databases.

The SQL script will be written to the standard output. Use the `[-f | --file]` option or shell operators to redirect it into a file.

`pg_dumpall` needs to connect several times to the WarehousePG coordinator server (once per database). If you use password authentication it is likely to ask for a password each time. It is convenient to have a `~/.pgpass` file in such cases.

Options

Dump Options

-a | --data-only Dump only the data, not the schema (data definitions). This option is only meaningful for the plain-text format. For the archive formats, you may specify the option when you call pg_restore.

-c | --clean Output commands to clean (drop) database objects prior to (the commands for) creating them. This option is only meaningful for the plain-text format. For the archive formats, you may specify the option when you call pg_restore.

-E encoding | --encoding=encoding Create the dump in the specified character set encoding. By default, the dump is created in the database encoding. (An alternate method to achieve the same result is to set the `PGCLIENTENCODING` environment variable to the desired dump encoding.)

-f filename | --file=filename Send output to the specified file. If this is omitted, `pg_dump` sends the output to standard out.

-g | --globals-only Dump only global objects (roles and tablespaces), no databases.

-O | --no-owner Do not output commands to set ownership of objects to match the original database. By default, pg_dump issues `ALTER OWNER` or `SET SESSION AUTHORIZATION` statements to set ownership of created database objects. These statements will fail when the script is run unless it is started by a superuser (or the same user that owns all of the objects in the script). To make a script that can be restored by any user, but will give that user ownership of all the objects, specify `-O`. This option is only meaningful for the plain-text format. For the archive formats, you may specify the option when you call pg_restore.

-r | --roles-only Dump only roles, not databases or tablespaces.

-s | --schema-only Dump only the object definitions (schema), not data.

-S username | --superuser=username Specify the superuser user name to use when deactivating triggers. This is relevant only if `--disable-triggers` is used. It is better to leave this out, and instead start the resulting script as a superuser.

```
> **Note** WarehousePG does not support user-defined triggers.
```

-t | --tablespaces-only Dump only tablespaces, not databases or roles.

-v | --verbose Specifies verbose mode. This will cause `[pg\_dump](pg_dump.html)` to output detailed object comments and start/stop times to the dump file, and progress messages to standard error.

-V | --version Print the `pg_dumpall` version and exit.

-x | --no-privileges | --no-acl Prevent dumping of access privileges (`GRANT/REVOKE` commands).

--binary-upgrade This option is for use by in-place upgrade utilities. Its use for other purposes is not recommended or supported. The behavior of the option may change in future releases without notice.

--column-inserts | --attribute-inserts Dump data as `INSERT` commands with explicit column names (`INSERT INTO <table> (<column>, ...) VALUES ...`). This will make restoration very slow; it is mainly useful for making dumps that can be loaded into non-PostgreSQL-based databases. Also, since this option generates a separate command for each row, an error in reloading a row causes only that row to be lost rather than the entire table contents.

--disable-dollar-quoting This option deactivates the use of dollar quoting for function bodies, and forces them to be quoted using SQL standard string syntax.

--disable-triggers This option is relevant only when creating a data-only dump. It instructs `pg_dumpall` to include commands to temporarily deactivate triggers on the target tables while the data is reloaded. Use this if you have triggers on the tables that you do not want to invoke during data reload. The commands emitted for `--disable-triggers` must be done as superuser. So, you should also specify a superuser name with `-S`, or preferably be careful to start the resulting script as a superuser.

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> **Note** WarehousePG does not support user-defined triggers.

--extra-float-digits=ndigits Use the specified value of `extra_float_digits` when dumping floating-point data, instead of the maximum available precision. Routine dumps made for backup purposes should not use this option.

--exclude-database=pattern Do not dump databases whose name matches pattern. Multiple patterns can be excluded by writing multiple `--exclude-database` switches. The pattern parameter is interpreted as a pattern according to the same rules used by `psql`'s `\d` commands, so multiple databases can also be excluded by writing wildcard characters in the pattern. When using wildcards, be careful to quote the pattern if needed to prevent shell wildcard expansion.

--if-exists Use conditional commands (for example, add an `IF EXISTS` clause) to drop databases and other objects. This option is not valid unless `--clean` is also specified.

--inserts Dump data as `INSERT` commands (rather than `COPY`). This will make restoration very slow; it is mainly useful for making dumps that can be loaded into non-PostgreSQL-based databases. Also, since this option generates a separate command for each row, an error in reloading a row causes only that row to be lost rather than the entire table contents. Note that the restore may fail altogether if you have rearranged column order. The `--column-inserts` option is safe against column order changes, though even slower.

--load-via-partition-root When dumping data for a table partition, make the `COPY` or `INSERT` statements target the root of the partitioning hierarchy that contains it, rather than the partition itself. This causes the appropriate partition to be re-determined for each row when the data is loaded. This may be useful when restoring data on a server where rows do not always fall into the same partitions as they did on the original server. That could happen, for example, if the partitioning column is of type `text` and the two systems have different definitions of the collation used to sort the partitioning column.

--lock-wait-timeout=timeout Do not wait forever to acquire shared table locks at the beginning of the dump. Instead, fail if unable to lock a table within the specified timeout. The timeout may be specified in any of the formats accepted by `SET statement_timeout`. Allowed values vary depending on the server version you are dumping from, but an integer number of milliseconds is accepted by all WarehousePG versions.

--no-comments Do not dump comments.

--no-role-passwords Do not dump passwords for roles. When restored, roles will have a null password, and password authentication will always fail until the password is set. Since password values are not required when this option is specified, the role information is read from the catalog view `pg_roles` instead of `pg_authid`. Consequently, this option also helps if access to `pg_authid` is restricted by some security policy.

--no-security-labels Do not dump security labels.

--no-sync By default, `pg_dumpall` waits for all files to be written safely to disk. Specifying this option causes `pg_dumpall` to return without waiting, which is faster, but implies that a subsequent operating system crash can leave the dump corrupt. This option is generally useful for testing, and should not be used when dumping data from a production installation.

--no-tablespaces Do not output commands to create tablespaces nor select tablespaces for objects. With this option, all objects will be created in whichever tablespace is the default during restore.

--no-unlogged-table-data Do not dump the contents of unlogged tables. This option has no effect on whether or not the table definitions (schema) are dumped; it only suppresses dumping the table data.

--on-conflict-do-nothing Add `ON CONFLICT DO NOTHING` to `INSERT` commands. This option is not valid unless `--inserts` or `--column-inserts` is also specified.

--quote-all-identifiers Force quoting of all identifiers. This option is recommended when dumping a database from a server whose WarehousePG major version is different from `pg_dumpall`'s, or when the output is intended to be loaded into a server of a different major version. By default, `pg_dumpall` quotes only identifiers that are reserved words in its own major version. This sometimes results in compatibility issues when dealing with servers of other versions that may have slightly different sets of reserved words. Using `--quote-all-identifiers` prevents such issues, at the price of a harder-to-read dump script.

--resource-queues Dump resource queue definitions.

--resource-groups Dump resource group definitions.

--rows-per-insert=nrows Dump data as `INSERT` commands (rather than `COPY)`. Controls the maximum number of rows per `INSERT` command. The value specified must be a number greater than zero. Any error during restoring will cause only rows that are part of the problematic `INSERT` to be lost, rather than the entire table contents.

--use-set-session-authorization Output SQL-standard `SET SESSION AUTHORIZATION` commands instead of `ALTER OWNER` commands to determine object ownership. This makes the dump more standards compatible, but depending on the history of the objects in the dump, may not restore properly. A dump using `SET SESSION AUTHORIZATION` requires superuser privileges to restore correctly, whereas `ALTER OWNER` requires lesser privileges.

--gp-syntax Output WarehousePG syntax in the `CREATE TABLE` statements. This allows the distribution policy (`DISTRIBUTED BY` or `DISTRIBUTED RANDOMLY` clauses) of a WarehousePG table to be dumped, which is useful for restoring into other WarehousePG clusters.

--no-gp-syntax Do not output the table distribution clauses in the `CREATE TABLE` statements.

-? | --help Show help about `pg_dumpall` command line arguments, and exit.

Connection Options

-d connstr | --dbname=connstr Specifies parameters used to connect to the server, as a connection string. See Connection Strings in the PostgreSQL documentation for more information.

The option is called `--dbname` for consistency with other client applications, but because `pg_dumpall` needs to connect to many databases, the database name in the connection string will be ignored. Use the `-l` option to specify the name of the database used to dump global objects and to discover what other databases should be dumped.

-h host | --host=host The host name of the machine on which the WarehousePG coordinator database server is running. If not specified, reads from the environment variable `PGHOST` or defaults to `localhost`.

-l dbname | --database=dbname Specifies the name of the database in which to connect to dump global objects. If not specified, the `postgres` database is used. If the `postgres` database does not exist, the `template1` database is used.

-p port | --port=port The TCP port on which the WarehousePG coordinator database server is listening for connections. If not specified, reads from the environment variable `PGPORT` or defaults to `5432`.

-U username | --username= username The database role name to connect as. If not specified, reads from the environment variable `PGUSER` or defaults to the current system role name.

-w | --no-password Never issue a password prompt. If the server requires password authentication and a password is not available by other means such as a `.pgpass` file the connection attempt will fail. This option can be useful in batch jobs and scripts where no user is present to enter a password.

-W | --password Force a password prompt. This option is never essential, since `pg_dumpall` will automatically prompt for a password if the server demands password authentication. However, `pg_dumpall` will waste a connection attempt finding out that the server wants a password. In some cases it is worth typing `-W` to avoid the extra connection attempt. Note that the password prompt will occur again for each database to be dumped. It may be preferable to set up a `~/.pgpass` file rather than to rely on manual password entry.

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--role=rolename Specifies a role name to be used to create the dump. This option causes `pg_dumpall` to issue a `SET ROLE <rolename>` command after connecting to the database. It is useful when the authenticated user (specified by `-U`) lacks privileges needed by `pg_dumpall`, but can switch to a role with the required rights. Some installations have a policy against logging in directly as a superuser, and use of this option allows dumps to be made without violating the policy.

Environment

PGHOST PGOPTIONS PGPORT PGUSER Default connection parameters.

PG_COLOR Specifies whether to use color in diagnostic messages. Possible values are `always`, `auto`, and `never`.

This utility also uses the environment variables supported by libpq.

Notes

Since `pg_dumpall` calls pg_dump internally, some diagnostic messages will refer to `pg_dump`.

The `--clean` option can be useful even when your intention is to restore the dump script into a fresh cluster. Use of `--clean` authorizes the script to drop and re-create the built-in `postgres` and `template1` databases, ensuring that those databases will retain the same properties (for instance, locale and encoding) that they had in the source cluster. Without the option, those databases will retain their existing database-level properties, as well as any pre-existing contents.

Once restored, it is wise to run `ANALYZE` on each database so the query planner has useful statistics. You can also run `vacuumdb -a -z` to vacuum and analyze all databases.

Do no expect the dump script to run completely without errors. In particular, because the script issues `CREATE ROLE` for every role existing in the source cluster, it is certain to generate a "role already exists" error for the bootstrap superuser, unless the destination cluster was initialized with a different bootstrap superuser name. This error is harmless and can be ignored. Use of the `--clean` option is likely to produce additional harmless error messages about non-existent objects; minimize those by adding `--if-exists`.

`pg_dumpall` requires all needed tablespace directories to exist before the restore; otherwise, database creation will fail for databases in non-default locations.

Examples

To dump all databases:

```
pg_dumpall > db.out
```

To reload database(s) from this file, you can use:

```
psql template1 -f db.out
```

To dump only global objects (including resource queues):

```
pg_dumpall -g --resource-queues
```

See Also

Check pg_dump for details on possible error conditions.

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7.7.2.35 pg_restore

Restores a database from an archive file created by `pg_dump`.

Synopsis

```
pg_restore [<connection-option> ...] [<restore_option> ...] [<filename>]

pg_restore -? | --help

pg_restore -V | --version
```

Description

`pg_restore` is a utility for restoring a database from an archive created by pg_dump in one of the non-plain-text formats. It will issue the commands necessary to reconstruct the database to the state it was in at the time it was saved. The archive files also allow `pg_restore` to be selective about what is restored, or even to reorder the items prior to being restored.

`pg_restore` can operate in two modes. If a database name is specified, the archive is restored directly into the database. Otherwise, a script containing the SQL commands necessary to rebuild the database is created and written to a file or standard output. The script output is equivalent to the plain text output format of `pg_dump`. Some of the options controlling the output are therefore analogous to `pg_dump` options.

`pg_restore` cannot restore information that is not present in the archive file. For instance, if the archive was made using the "dump data as `INSERT` commands" option, `pg_restore` will not be able to load the data using `COPY` statements.

Options

filename Specifies the location of the archive file (or directory, for a directory-format archive) to be restored. If not specified, the standard input is used.

Restore Options

-a | --data-only Restore only the data, not the schema (data definitions). Table data and sequence values are restored, if present in the archive.

```
This option is similar to, but for historical reasons not identical to, specifying `--section=data`.
```

-c | --clean Clean (drop) database objects before recreating them. (If you do not also specify `--if-exists`, this may generate some harmless error messages if any objects were not present in the destination database.)

-C | --create Create the database before restoring into it. If `--clean` is also specified, drop and recreate the target database before connecting to it.

With `--create`, `pg_restore` also restores the database's comment if any, and any configuration variable settings that are specific to this database, that is, any `ALTER DATABASE ... SET ...` and `ALTER ROLE ... IN DATABASE ... SET ...` commands that mention this database. Access privileges for the database itself are also restored, unless `--no-acl` is specified.

When this option is used, the database named with `-d` is used only to issue the initial `DROP DATABASE` and `CREATE DATABASE` commands. All data is restored into the database name that appears in the archive.

-d dbname | --dbname=dbname Connect to this database and restore directly into this database. The dbname can be aConnection Strings. If so, connection string parameters override any conflicting command line options.

-e | --exit-on-error Exit if an error is encountered while sending SQL commands to the database. The default is to continue and to display a count of errors at the end of the restoration.

-f outfilename | --file=outfilename Specify output file for generated script, or for the listing when used with `-l`. Use `-` for `stdout`.

-F c|d|t | --format={custom | directory | tar} The format of the archive produced by pg_dump. It is not necessary to specify the format, since `pg_restore` will determine the format automatically. Format can be `custom`, `directory`, or `tar`.

-I index | --index=index Restore definition of named index only. You can specify multiple indexes with multiple `-I` switches.

-j | --number-of-jobs | --jobs=number-of-jobs Run the most time-consuming parts of `pg_restore` — those which load data, create indexes, or create constraints — using multiple concurrent jobs. This option can dramatically reduce the time to restore a large database to a server running on a multiprocessor machine. This option is ignored when emitting a script rather than connecting directly to a database server.

Each job is one process or one thread, depending on the operating system, and uses a separate connection to the server.

The optimal value for this option depends on the hardware setup of the server, of the client, and of the network. Factors include the number of CPU cores and the disk setup. A good place to start is the number of CPU cores on the server, but values larger than that can also lead to faster restore times in many cases. Of course, values that are too high will lead to decreased performance because of thrashing.

Only the custom and directory archive formats ase supported with this option. The input file must be a regular file or directory (not, for example, a pipe or standard input). Also, multiple jobs cannot be used together with the option `--single-transaction`.

-l | --list List the table contents of the archive. The output of this operation can be used as input to the `-L` option. Note that if filtering switches such as `-n` or `-t` are used with `-l`, they restrict the items listed.

-L list-file | --use-list=list-file Restore only those archive elements that are listed in list-file, and restore them in the order they appear in the file. Note that if filtering switches such as `-n` or `-t` are used with `-L`, they further restrict the items restored.

list-file is normally created by editing the output of a previous `-l` operation. Lines can be moved or removed, and can also be commented out by placing a semicolon `;`) at the start of the line. See below for examples.

-n schema | --schema=schema Restore only objects that are in the named schema. You can specify multiple schemas with multiple `-n` switches. Combine with the `-t` option to restore just a specific table.

-N schema | --exclude-schema=schema Do not restore objects that are in the named schema. You can specify multiple schemas to exclude with multiple `-N` switches.

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When both `-n` and `-N` are specified for the same schema name, the `-N` switch takes precedence and the schema is excluded.

-O | --no-owner Do not output commands to set ownership of objects to match the original database. By default, `pg_restore` issues `ALTER OWNER` or `SET SESSION AUTHORIZATION` statements to set ownership of created schema elements. These statements will fail unless the initial connection to the database is made by a superuser (or the same user that owns all of the objects in the script). With `-O`, any user name can be used for the initial connection, and this user will own all the created objects.

-P function-name(argtype [, ...]) | --function=function-name(argtype [, ...]) Restore the named function only. The function name must be enclosed in quotes. Be careful to spell the function name and arguments exactly as they appear in the dump file's table of contents (as shown by the `--list` option). You can specify multiple functions with multiple `-P` switches.

-s | --schema-only Restore only the schema (data definitions), not data, to the extent that schema entries are present in the archive.

This option is the inverse of `--data-only`. It is similar to, but for historical reasons not identical to, specifying `--section=pre-data --section=post-data`.

(Do not confuse this with the `--schema` option, which uses the word *schema* in a different meaning.)

-S username | --superuser=username Specify the superuser user name to use when deactivating triggers. This is only relevant if `--disable-triggers` is used.

```
> **Note** WarehousePG does not support user-defined triggers.
```

-t table | --table=table Restore definition and/or data of the named table only. "table" includes views, materialized views, sequences, and foreign tables. You can specify multiple tables with multiple `-t` switches. Combine this option with the `-n` option to specify table(s) in a particular schema. When you specify `-t`, `pg_restore` makes no attempt to restore any other database objects that the selected table(s) might depend upon. Therefore, there is no guarantee that a specific-table restore into a clean database will succeed. This option does not behave identically to the `-t` option of `pg_dump`. `pg_restore` does not currently support wild-card matching, nor can you include a schema name within its `-t`. And, while `pg_dump`'s `-t` flag will also dump subsidiary objects (such as indexes) of the selected table(s), `pg_restore`'s `-t` flag does not include such subsidiary objects.

```
> **Note** In versions prior to WarehousePG 7, this flag matched only tables, not any other type of relation.
```

-T trigger | --trigger=trigger Restore named trigger only.

```
> **Note** WarehousePG does not support user-defined triggers.
```

-v | --verbose Specifies verbose mode.

-V | --version Print the `pg_restore` version and exit.

-x | --no-privileges | --no-acl Prevent restoration of access privileges (`GRANT/REVOKE` commands).

-1 | --single-transaction Run the restore as a single transaction (that is, wrap the emitted commands in `BEGIN` / `COMMIT1). This ensures that either all of the commands complete successfully, or no changes are applied. This option implies` --exit-on-error`.

--disable-triggers This option is relevant only when performing a data-only restore. It instructs `pg_restore` to run commands to temporarily deactivate triggers on the target tables while the data is reloaded. Use this if you have triggers on the tables that you do not want to invoke during data reload. The commands emitted for `--disable-triggers` must be invoked as superuser. So you should also specify a superuser name with `-S` or, preferably, run `pg_restore` as a superuser.

```
> **Note** WarehousePG does not support user-defined triggers.
```

--enable-row-security This option is relevant only when restoring the contents of a table which has row security. By default, `pg_restore` sets `row_security` to off, to ensure that all data is restored in to the table. If the user does not have sufficient privileges to bypass row security, then an error is thrown. This parameter instructs `pg_restore` to set `row_security` to on instead, allowing the user to attempt to restore the contents of the table with row security enabled. This might still fail if the user does not have the right to insert the rows from the dump into the table.

This option currently also requires the dump be in `INSERT` format, as `COPY FROM` does not support row security.

--if-exists Use conditional commands (for example, add an `IF EXISTS` clause) to drop database objects. This option is not valid unless `--clean` is also specified.

--no-comments Do not output commands to restore comments, even if the archive contains them.

--no-data-for-failed-tables By default, table data is restored even if the creation command for the table failed (for example, because it already exists). With this option, data for such a table is skipped. This behavior is useful when the target database may already contain the desired table contents. Specifying this option prevents duplicate or obsolete data from being loaded. This option is effective only when restoring directly into a database, not when producing SQL script output.

--no-security-labels Do not output commands to restore security labels, even if the archive contains them.

--no-tablespaces Do not output commands to select tablespaces. With this option, all objects will be created in whichever tablespace is the default during restore.

--section=sectionname Only restore the named section. The section name can be `pre-data`, `data`, or `post-data`. This option can be specified more than once to select multiple sections. The data section contains actual table data. Post-data items consist of definitions of indexes, triggers, rules, and constraints other than validated check constraints. Pre-data items consist of all other data definition items. The default is to restore all sections.

--strict-names Require that each schema (`-n` / `--schema`) and table (`-t` / `--table`) qualifier match at least one schema/table in the backup file.

--use-set-session-authorization Output SQL-standard `SET SESSION AUTHORIZATION` commands instead of `ALTER OWNER` commands to determine object ownership. This makes the dump more standards-compatible, but depending on the history of the objects in the dump, it might not restore properly.

-? | --help Show help about `pg_restore` command line arguments, and exit.

Connection Options

-h host | --host host The host name of the machine on which the WarehousePG coordinator database server is running. If not specified, reads from the environment variable `PGHOST` or defaults to `localhost`.

-p port | --port port The TCP port on which the WarehousePG coordinator database server is listening for connections. If not specified, reads from the environment variable `PGPORT` or defaults to `5432`.

-U username | --username username The database role name to connect as. If not specified, reads from the environment variable `PGUSER` or defaults to the current system role name.

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-w | --no-password Never issue a password prompt. If the server requires password authentication and a password is not available by other means such as a `.pgpass` file the connection attempt will fail. This option can be useful in batch jobs and scripts where no user is present to enter a password.

-W | --password Force a password prompt.

This option is never required, since `pg_restore` automatically prompts for a password if the server demands password authentication. However, `pg_restore` will waste a connection attempt determinig that the server wants a password. In some cases it is worth typing `-W` to avoid the extra connection attempt.

--role=rolename Specifies a role name to be used to perform the restore. This option causes `pg_restore` to issue a `SET ROLE <rolename>` command after connecting to the database. It is useful when the authenticated user (specified by `-U`) lacks privileges needed by `pg_restore`, but can switch to a role with the required rights. Some installations have a policy against logging in directly as a superuser, and use of this option allows restores to be performed without violating the policy.

Environment

PGHOST PGOPTIONS PGPORT PGUSER Default connection parameters.

PG_COLOR Specifies whether to use color in diagnostic messages. Possible values are `always`, `auto`, and `never`.

This utility also uses the environment variables supported by libpq.

Diagnostics

When you specify a direct database connection using the `-d` option, `pg_restore` internally executes SQL statements. If you have problems running `pg_restore`, make sure you are able to select information from the database using, for example, `psql`. Also, any default connection settings and environment variables used by the `libpq` front-end library will apply.

Notes

If your installation has any local additions to the `template1` database, be careful to load the output of `pg_restore` into a truly empty database; otherwise you are likely to get errors due to duplicate definitions of the added objects. To make an empty database without any local additions, copy from `template0` not `template1`, for example:

```
CREATE DATABASE foo WITH TEMPLATE template0;
```

When restoring data to a pre-existing table and the option `--disable-triggers` is used, `pg_restore` emits commands to deactivate triggers on user tables before inserting the data, then emits commands to re-enable them after the data has been inserted. If the restore is stopped in the middle, the system catalogs may be left in the wrong state.

See also the pg_dump documentation for details on limitations of `pg_dump`.

Once restored, it is wise to run `ANALYZE` on each restored table so the query planner has useful statistics.

Examples

Assume we have dumped a database called `mydb` into a custom-format dump file:

```
pg_dump -Fc mydb > db.dump
```

To drop the database and recreate it from the dump:

```
dropdb mydb
pg_restore -C -d template1 db.dump
```

Run the following commands to reload the dump into a new database called `newdb`. Notice there is no `-C` option provided. Instead, connect directly to the database to which to restore to. Also note that the new database is cloned from `template0` not `template1`, to ensure that it is initially empty:

```
createdb -T template0 newdb
pg_restore -d newdb db.dump
```

To reorder database items, you must first dump the table of contents of the archive:

```
pg_restore -l db.dump > db.list
```

The listing file consists of a header and one line for each item, for example,

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```
; Archive created at Mon Sep 14 13:55:39 2019
;     dbname: DBDEMOS
;     TOC Entries: 81
;     Compression: 9
;     Dump Version: 1.10-0
;     Format: CUSTOM
;     Integer: 4 bytes
;     Offset: 8 bytes
;     Dumped from database version: 9.4.24
;     Dumped by pg_dump version: 9.4.24
;
; Selected TOC Entries:
;
3; 2615 2200 SCHEMA - public pasha
1861; 0 0 COMMENT - SCHEMA public pasha
1862; 0 0 ACL - public pasha
317; 1247 17715 TYPE public composite pasha
319; 1247 25899 DOMAIN public domain0 pasha2
```

Semicolons start a comment, and the numbers at the start of lines refer to the internal archive ID assigned to each item. You can comment out, delete, and reorder lines in the file. For example:

```
10; 145433 TABLE map_resolutions postgres
;2; 145344 TABLE species postgres
;4; 145359 TABLE nt_header postgres
6; 145402 TABLE species_records postgres
;8; 145416 TABLE ss_old postgres
```

You can use this file as input to `pg_restore`, to restore only items 10 and 6, in that order:

```
pg_restore -L db.list db.dump
```

See Also

pg_dump, pg_dumpall, psql

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7.7.2.36 psql

Interactive command-line interface for WarehousePG

Synopsis

```
psql [<option> ...] [<dbname> [<username>]]
```

Description

`psql` is a terminal-based front-end to WarehousePG. It enables you to type in queries interactively, issue them to WarehousePG, and see the query results. Alternatively, input can be from a file. In addition, it provides a number of meta-commands and various shell-like features to facilitate writing scripts and automating a wide variety of tasks.

Options

-a | --echo-all Print all nonempty input lines to standard output as they are read. (This does not apply to lines read interactively.) This is equivalent to setting the variable ECHO to `all`.

-A | --no-align Switches to unaligned output mode. (The default output mode is aligned.)

-c 'command' | --command='command' Specifies that `psql` is to run the specified command string, and then exit. This is useful in shell scripts. command must be either a command string that is completely parseable by the server, or a single backslash command. Thus you cannot mix SQL and `psql` meta-commands with this option. To achieve that, you could pipe the string into `psql`, like this:

```
```
echo '\x \\ SELECT * FROM foo;' | psql
```
```

(`\\` is the separator meta-command.)

If the command string contains multiple SQL commands, they are processed in a single transaction, unless there are explicit `BEGIN/COMMIT` commands included in the string to divide it into multiple transactions. This is different from the behavior when the same string is fed to `psql`'s standard input. Also, only the result of the last SQL command is returned.

-d dbname | --dbname=dbname Specifies the name of the database to connect to. This is equivalent to specifying dbname as the first non-option argument on the command line.

If this parameter contains an `=` sign or starts with a valid URI prefix (`postgresql://` or `postgres://`), it is treated as a `conninfo` string. See Connection Strings in the PostgreSQL documentation for more information.

-e | --echo-queries Copy all SQL commands sent to the server to standard output as well.

-E | --echo-hidden Echo the actual queries generated by `\d` and other backslash commands. You can use this to study `psql`'s internal operations. This is equivalent to setting the variable ECHO_HIDDEN to `on`.

-f filename | --file=filename Use the file filename as the source of commands instead of reading commands interactively. After the file is processed, `psql` terminates. This is in many ways equivalent to the meta-command `\i`.

If filename is `-` (hyphen), then standard input is read until an EOF indication or `\q` meta-command. Note however that Readline is not used in this case (much as if `-n` had been specified).

Using this option is subtly different from writing `psql < <filename>`. In general, both will do what you expect, but using `-f` enables some nice features such as error messages with line numbers. There is also a slight chance that using this option will reduce the start-up overhead. On the other hand, the variant using the shell's input redirection is (in theory) guaranteed to yield exactly the same output you would have received had you entered everything by hand.

-F separator | --field-separator=separator Use the specified separator as the field separator for unaligned output.

-H | --html Turn on HTML tabular output.

-l | --list List all available databases, then exit. Other non-connection options are ignored.

-L filename | --log-file=filename Write all query output into the specified log file, in addition to the normal output destination.

-n | --no-readline Do not use Readline for line editing and do not use the command history. This can be useful to turn off tab expansion when cutting and pasting.

-o filename | --output=filename Put all query output into the specified file.

-P assignment | --pset=assignment Allows you to specify printing options in the style of `\pset` on the command line. Note that here you have to separate name and value with an equal sign instead of a space. Thus to set the output format to `LaTeX`, you could write `-P format=latex`.

-q | --quiet Specifies that `psql` should do its work quietly. By default, it prints welcome messages and various informational output. If this option is used, none of this happens. This is useful with the `-c` option. This is equivalent to setting the variable QUIET to `on`.

-R separator | --record-separator=separator Use separator as the record separator for unaligned output.

-s | --single-step Run in single-step mode. That means the user is prompted before each command is sent to the server, with the option to cancel execution as well. Use this to debug scripts.

-S | --single-line Runs in single-line mode where a new line terminates an SQL command, as a semicolon does.

-t | --tuples-only Turn off printing of column names and result row count footers, etc. This command is equivalent to `\pset tuples_only` and is provided for convenience.

-T table_options | --table-attr= table_options Allows you to specify options to be placed within the HTML table tag. See `\pset` for details.

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-v assignment | --set=assignment | --variable= assignment Perform a variable assignment, like the `\set` meta command. Note that you must separate name and value, if any, by an equal sign on the command line. To unset a variable, leave off the equal sign. To set a variable with an empty value, use the equal sign but leave off the value. These assignments are done during a very early stage of start-up, so variables reserved for internal purposes might get overwritten later.

-V | --version Print the `psql` version and exit.

-x | --expanded Turn on the expanded table formatting mode.

-X | --no-psqlrc Do not read the start-up file (neither the system-wide `psqlrc` file nor the user's `~/.psqlrc` file).

-z | --field-separator-zero Set the field separator for unaligned output to a zero byte.

-0 | --record-separator-zero Set the record separator for unaligned output to a zero byte. This is useful for interfacing, for example, with `xargs -0`.

-1 | --single-transaction When `psql` runs a script, adding this option wraps `BEGIN`/`COMMIT` around the script to run it as a single transaction. This ensures that either all the commands complete successfully, or no changes are applied.

If the script itself uses `BEGIN`, `COMMIT`, or `ROLLBACK`, this option will not have the desired effects. Also, if the script contains any command that cannot be run inside a transaction block, specifying this option will cause that command (and hence the whole transaction) to fail.

-? | --help Show help about `psql` command line arguments, and exit.

Connection Options

-h host | --host=host The host name of the machine on which the WarehousePG coordinator database server is running. If not specified, reads from the environment variable `PGHOST` or defaults to localhost.

When starting `psql` on the coordinator host, if the host value begins with a slash, it is used as the directory for the UNIX-domain socket.

-p port | --port=port The TCP port on which the WarehousePG coordinator database server is listening for connections. If not specified, reads from the environment variable `PGPORT` or defaults to 5432.

-U username | --username=username The database role name to connect as. If not specified, reads from the environment variable `PGUSER` or defaults to the current system role name.

-W | --password Force a password prompt. `psql` should automatically prompt for a password whenever the server requests password authentication. However, currently password request detection is not totally reliable, hence this option to force a prompt. If no password prompt is issued and the server requires password authentication, the connection attempt will fail.

-w --no-password Never issue a password prompt. If the server requires password authentication and a password is not available by other means such as a .pgpass file, the connection attempt will fail. This option can be useful in batch jobs and scripts where no user is present to enter a password.

> **Note** This option remains set for the entire session, and so it affects uses of the meta-command `\connect` as well as the initial connection attempt.

Exit Status

`psql` returns 0 to the shell if it finished normally, 1 if a fatal error of its own (out of memory, file not found) occurs, 2 if the connection to the server went bad and the session was not interactive, and 3 if an error occurred in a script and the variable `ON_ERROR_STOP` was set.

Usage

Connecting to a Database

`psql` is a client application for WarehousePG. In order to connect to a database you need to know the name of your target database, the host name and port number of the WarehousePG coordinator server and what database user name you want to connect as. `psql` can be told about those parameters via command line options, namely `-d`, `-h`, `-p`, and `-U` respectively. If an argument is found that does not belong to any option it will be interpreted as the database name (or the user name, if the database name is already given). Not all of these options are required; there are useful defaults. If you omit the host name, `psql` will connect via a UNIX-domain socket to a coordinator server on the local host, or via TCP/IP to `localhost` on machines that do not have UNIX-domain sockets. The default coordinator port number is 5432. If you use a different port for the coordinator, you must specify the port. The default database user name is your operating-system user name, as is the default database name. Note that you cannot just connect to any database under any user name. Your database administrator should have informed you about your access rights.

When the defaults are not right, you can save yourself some typing by setting any or all of the environment variables `PGAPPNAME`, `PGDATABASE`, `PGHOST`, `PGPORT`, and `PGUSER` to appropriate values.

It is also convenient to have a `~/.pgpass` file to avoid regularly having to type in passwords. This file should reside in your home directory and contain lines of the following format:

```
<hostname>:<port>:<database>:<username>:<password>
```

The permissions on `.pgpass` must disallow any access to world or group (for example: `chmod 0600 ~/.pgpass`). If the permissions are less strict than this, the file will be ignored. (The file permissions are not currently checked on Microsoft Windows clients, however.)

An alternative way to specify connection parameters is in a `conninfo` string or a URI, which is used instead of a database name. This mechanism gives you very wide control over the connection. For example:

```
$ psql "service=myservice sslmode=require"
$ psql postgresql://gpcoordinator:5433/mydb?sslmode=require
```

This way you can also use LDAP for connection parameter lookup as described in LDAP Lookup of Connection Parameters in the PostgreSQL documentation. See Parameter Keywords in the PostgreSQL documentation for more information on all the available connection options.

If the connection could not be made for any reason (insufficient privileges, server is not running, etc.), `psql` will return an error and terminate.

If at least one of standard input or standard output are a terminal, then `psql` sets the client encoding to `auto`, which will detect the appropriate client encoding from the locale settings (`LC_CTYPE` environment variable on Unix systems). If this doesn't work out as expected, the client encoding can be overridden using the environment variable `PGCLIENTENCODING`.

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Entering SQL Commands

In normal operation, `psql` provides a prompt with the name of the database to which `psql` is currently connected, followed by the string **=>** for a regular user or **=#** for a superuser. For example:

```
testdb=>
testdb=#
```

At the prompt, the user may type in SQL commands. Ordinarily, input lines are sent to the server when a command-terminating semicolon is reached. An end of line does not terminate a command. Thus commands can be spread over several lines for clarity. If the command was sent and run without error, the results of the command are displayed on the screen.

If untrusted users have access to a database that has not adopted a secure schema usage pattern, begin your session by removing publicly-writable schemas from search_path. You can add `options=-csearch_path=` to the connection string or issue `SELECT pg_catalog.set_config('search_path', '', false)` before other SQL commands. This consideration is not specific to `psql`; it applies to every interface for running arbitrary SQL commands.

Meta-Commands

Anything you enter in `psql` that begins with an unquoted backslash is a `psql` meta-command that is processed by `psql` itself. These commands help make `psql` more useful for administration or scripting. Meta-commands are more commonly called slash or backslash commands.

The format of a `psql` command is the backslash, followed immediately by a command verb, then any arguments. The arguments are separated from the command verb and each other by any number of whitespace characters.

To include whitespace into an argument you may quote it with single quotes. To include a single quote into such an argument, write two single quotes within single-quoted text. Anything contained in single quotes is furthermore subject to C-like substitutions for `\n` (new line), `\t` (tab), `\b` (backspace), `\r` (carriage return), `\f` (form feed), `\digits` (octal), and `\xdigits` (hexadecimal). A backslash preceding any other character within single-quoted text quotes that single character, whatever it is.

Within an argument, text that is enclosed in backquotes (```) is taken as a command line that is passed to the shell. The output of the command (with any trailing newline removed) replaces the backquoted text.

If an unquoted colon (`:`) followed by a `psql` variable name appears within an argument, it is replaced by the variable's value, as described in SQL Interpolation.

Some commands take an SQL identifier (such as a table name) as argument. These arguments follow the syntax rules of SQL: Unquoted letters are forced to lowercase, while double quotes (`"`) protect letters from case conversion and allow incorporation of whitespace into the identifier. Within double quotes, paired double quotes reduce to a single double quote in the resulting name. For example, `FOO"BAR"BAZ` is interpreted as `fooBARbaz`, and `"A weird"" name"` becomes `A weird" name`.

Parsing for arguments stops when another unquoted backslash occurs. This is taken as the beginning of a new meta-command. The special sequence `\\` (two backslashes) marks the end of arguments and continues parsing SQL commands, if any. That way SQL and `psql` commands can be freely mixed on a line. But in any case, the arguments of a meta-command cannot continue beyond the end of the line.

The following meta-commands are defined:

\a If the current table output format is unaligned, it is switched to aligned. If it is not unaligned, it is set to unaligned. This command is kept for backwards compatibility. See `\pset` for a more general solution.

\c | \connect [dbname [username] [host] [port]] | conninfo Establishes a new WarehousePG connection. The connection parameters to use can be specified either using a positional syntax, or using `conninfo` connection strings as detailed in libpq Connection Strings.

Where the command omits database name, user, host, or port, the new connection can reuse values from the previous connection. By default, values from the previous connection are reused except when processing a `conninfo` string. Passing a first argument of `-reuse-previous=on` or `-reuse-previous=off` overrides that default. When the command neither specifies nor reuses a particular parameter, the `libpq` default is used. Specifying any of dbname, username, host or port as `-` is equivalent to omitting that parameter.

If the new connection is successfully made, the previous connection is closed. If the connection attempt failed, the previous connection will only be kept if `psql` is in interactive mode. When running a non-interactive script, processing will immediately stop with an error. This distinction was chosen as a user convenience against typos, and a safety mechanism that scripts are not accidentally acting on the wrong database.

Examples:

```
```
=> \c mydb myuser host.dom 6432
=> \c service=foo
=> \c "host=localhost port=5432 dbname=mydb connect_timeout=10 sslmode=disable"
=> \c postgresql://tom@localhost/mydb?application_name=myapp
```
```

\C [title] Sets the title of any tables being printed as the result of a query or unset any such title. This command is equivalent to `\pset title`.

\cd [directory] Changes the current working directory. Without argument, changes to the current user's home directory. To print your current working directory, use `\!pwd`.

\conninfo Displays information about the current connection including the database name, the user name, the type of connection (UNIX domain socket, `TCP/IP`, etc.), the host, and the port.

\copy {table [(column_list)] | (query)} {from | to} {'filename' | program 'command' | stdin | stdout | pstdin | pstdout} [with] (option [, ...])] Performs a frontend (client) copy. This is an operation that runs an SQL `[COPY](../../ref_guide/sql_commands/COPY.html)` command, but instead of the server reading or writing the specified file, `psql` reads or writes the file and routes the data between the server and the local file system. This means that file accessibility and privileges are those of the local user, not the server, and no SQL superuser privileges are required.

When `program` is specified, command is run by `psql` and the data from or to command is routed between the server and the client. This means that the execution privileges are those of the local user, not the server, and no SQL superuser privileges are required.

`\copy ... from stdin | to stdout` reads/writes based on the command input and output respectively. All rows are read from the same source that issued the command, continuing until `\.` is read or the stream reaches `EOF`. Output is sent to the same place as command output. To read/write from `psql`'s standard input or output, use `pstdin` or `pstdout`. This option is useful for populating tables in-line within a SQL script file.

The syntax of the command is similar to that of the SQL COPY command, and option must indicate one of the options of the SQL `COPY` command. Note that, because of this, special parsing rules apply to the `\copy` command. In particular, the variable substitution rules and backslash escapes do not apply.

This operation is not as efficient as the SQL `COPY` command because all data must pass through the client/server connection.

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\d [relation_pattern] | \d+ [relation_pattern] | \dS [relation_pattern] For each relation (table, external table, view, materialized view, index, sequence, or foreign table) or composite type matching the relation pattern, show all columns, their types, the tablespace (if not the default) and any special attributes such as `NOT NULL` or defaults. Associated indexes, constraints, rules, and triggers are also shown. For foreign tables, the associated foreign server is shown as well.

```
-   For some types of relation, `\d` shows additional information for each column: column values for sequences, indexed expressions for indexes, and foreign data wrapper options for foreign tables.
-   The command form `\d+` is identical, except that more information is displayed: any comments associated with the columns of the table are shown, as is the presence of OIDs in the table, the view definition if the relation is a view.
    <br/><br/>For partitioned tables, the command `\d` or `\d+` specified with the root partitioned table or a child table displays information about the table including partition keys on the current level of the partitioned table. The command `\d+` also displays the immediate child partitions of the table and whether the partition is an external table or regular table.
    <br/><br/>For append-optimized tables and column-oriented tables, `\d+` displays the storage options for a table. For append-optimized tables, the options are displayed for the table. For column-oriented tables, storage options are displayed for each column.

-   By default, only user-created objects are shown; supply a pattern or the `S` modifier to include system objects.
    <br/><br/>> **Note** If `\d` is used without a pattern argument, it is equivalent to `\dtvmsE` which will show a list of all visible tables, views, materialized views, sequences, and foreign tables.
```

\da[S] [aggregate_pattern] Lists aggregate functions, together with the data types they operate on. If a pattern is specified, only aggregates whose names match the pattern are shown. By default, only user-created objects are shown; supply a pattern or the `S` modifier to include system objects.

\db[+] [tablespace_pattern] Lists all available tablespaces and their corresponding paths. If pattern is specified, only tablespaces whose names match the pattern are shown. If + is appended to the command name, each object is listed with its associated permissions.

\dc[S+] [conversion_pattern] Lists conversions between character-set encodings. If a pattern is specified, only conversions whose names match the pattern are listed. By default, only user-created objects are shown; supply a pattern or the `S` modifier to include system objects. If `+` is appended to the command name, each object is listed with its associated description.

\dC[+] [pattern] Lists type casts. If a pattern is specified, only casts whose source or target types match the pattern are listed. If `+` is appended to the command name, each object is listed with its associated description.

\dd[S] [pattern] Shows the descriptions of objects of type `constraint`, `operator class`, `operator family`, `rule`, and `trigger`. All other comments may be viewed by the respective backslash commands for those object types.

`\dd` displays descriptions for objects matching the pattern, or of visible objects of the appropriate type if no argument is given. But in either case, only objects that have a description are listed. By default, only user-created objects are shown; supply a pattern or the `S` modifier to include system objects.

Descriptions for objects can be created with the `COMMENT` SQL command.

\ddp [pattern] Lists default access privilege settings. An entry is shown for each role (and schema, if applicable) for which the default privilege settings have been changed from the built-in defaults. If pattern is specified, only entries whose role name or schema name matches the pattern are listed.

The ALTER DEFAULT PRIVILEGES command is used to set default access privileges. The meaning of the privilege display is explained under GRANT.

\dD[S+] [domain_pattern] Lists domains. If a pattern is specified, only domains whose names match the pattern are shown. By default, only user-created objects are shown; supply a pattern or the `S` modifier to include system objects. If `+` is appended to the command name, each object is listed with its associated permissions and description.

\dEimstPv[S+] [external_table | index | materialized_view | sequence | table | parent table | view] This is not the actual command name: the letters `E`, `i`, `m`, `s`, `t`, `P`, and `v` stand for external table, index, materialized view, sequence, table, parent table, and view, respectively. You can specify any or all of these letters, in any order, to obtain a listing of objects of these types. For example, `\dit` lists indexes and tables. If `+` is appended to the command name, each object is listed with its physical size on disk and its associated description, if any. If a pattern is specified, only objects whose names match the pattern are listed. By default, only user-created objects are shown; supply a pattern or the `S` modifier to include system objects.

\des[+] [foreign_server_pattern] Lists foreign servers. If a pattern is specified, only those servers whose name matches the pattern are listed. If the form `\des+` is used, a full description of each server is shown, including the server's ACL, type, version, options, and description.

\det[+] [foreign_table_pattern] Lists all foreign tables. If a pattern is specified, only entries whose table name or schema name matches the pattern are listed. If the form `\det+` is used, generic options and the foreign table description are also displayed.

\deu[+] [user_mapping_pattern] Lists user mappings. If a pattern is specified, only those mappings whose user names match the pattern are listed. If the form `\deu+` is used, additional information about each mapping is shown.

```
> **Caution** `\deu+` might also display the user name and password of the remote user, so care should be taken not to disclose them.
```

\dew[+] [foreign_data_wrapper_pattern] Lists foreign-data wrappers. If a pattern is specified, only those foriegn-data wrappers whose name matches the pattern are listed. If the form `\dew+` is used, the ACL, options, and description of the foreign-data wrapper are also shown.

\df[antwS+] [function_pattern] Lists functions, together with their arguments, return types, and function types, which are classified as "agg" (aggregate), "normal", "trigger", or "window". To display only functions of a specific type(s), add the corresponding letters `a`, `n`, `t`, or `w`, to the command. If a pattern is specified, only functions whose names match the pattern are shown. If the form `\df+` is used, additional information about each function, including security, volatility, language, source code, and description, is shown. By default, only user-created objects are shown; supply a pattern or the `S` modifier to include system objects.

\dF[+] [pattern] Lists text search configurations. If a pattern is specified, only configurations whose names match the pattern are shown. If the form `\dF+` is used, a full description of each configuration is shown, including the underlying text search parser and the dictionary list for each parser token type.

\dFd[+] [pattern] Lists text search dictionaries. If a pattern is specified, only dictionaries whose names match the pattern are shown. If the form `\dFd+` is used, additional information is shown about each selected dictionary, including the underlying text search template and the option values.

\dFp[+] [pattern] Lists text search parsers. If a pattern is specified, only parsers whose names match the pattern are shown. If the form `\dFp+` is used, a full description of each parser is shown, including the underlying functions and the list of recognized token types.

\dFt[+] [pattern] Lists text search templates. If a pattern is specified, only templates whose names match the pattern are shown. If the form `\dFt+` is used, additional information is shown about each template, including the underlying function names.

\dg[+] [role_pattern] Lists database roles. (Since the concepts of "users" and "groups" have been unified into "roles", this command is now equivalent to `\du`.) If a pattern is specified, only those roles whose names match the pattern are listed. If the form `\dg+` is used, additional information is shown about each role; currently this adds the comment for each role.

\dl This is an alias for `\lo_list`, which shows a list of large objects.

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> **Note** WarehousePG does not support the PostgreSQL [large object facility](https://www.postgresql.org/docs/12/largeobjects.html) for streaming user data that is stored in large-object structures.

\dL[S+] [pattern] Lists procedural languages. If a pattern is specified, only languages whose names match the pattern are listed. By default, only user-created languages are shown; supply the `S` modifier to include system objects. If `+` is appended to the command name, each language is listed with its call handler, validator, access privileges, and whether it is a system object.

\dn[S+] [schema_pattern] Lists all available schemas (namespaces). If a pattern is specified, only schemas whose names match the pattern are listed. By default, only user- create objects are show; supply a pattern or the `S` modifier to include system objects. If `+` is appended to the command name, each object is listed with its associated permissions and description, if any.

\do[S] [operator_pattern] Lists available operators with their operand and return types. If a pattern is specified, only operators whose names match the pattern are listed. By default, only user-created objects are shown; supply a pattern or the `S` modifier to include system objects.

\dO[S+] [pattern] Lists collations. If a pattern is specified, only collations whose names match the pattern are listed. By default, only user-created objects are shown; supply a pattern or the `S` modifier to include system objects. If `+` is appended to the command name, each collation is listed with its associated description, if any. Note that only collations usable with the current database's encoding are shown, so the results may vary in different databases of the same installation.

\dp [relation_pattern_to_show_privileges] Lists tables, views, and sequences with their associated access privileges. If a pattern is specified, only tables, views, and sequences whose names match the pattern are listed. TheGRANT and REVOKE commands are used to set access privileges. The meaning of the privilege display is explained under GRANT.

\drds [role-pattern [database-pattern]] Lists defined configuration settings. These settings can be role-specific, database-specific, or both. role-pattern and database-pattern are used to select specific roles and database to list, respectively. If omitted, or if `*` is specified, all settings are listed, including those not role-specific or database-specific, respectively.

The ALTER ROLE and ALTER DATABASE commands are used to define per-role and per-database role configuration settings.

\dT[S+] [datatype_pattern] Lists data types. If a pattern is specified, only types whose names match the pattern are listed. If `+` is appended to the command name, each type is listed with its internal name and size, its allowed values if it is an `enum` type, and its associated permissions. By default, only user-created objects are shown; supply a pattern or the `S` modifier to include system objects.

\du[+] [role_pattern] Lists database roles. (Since the concepts of "users" and "groups" have been unified into "roles", this command is now equivalent to `\dg`.) If a pattern is specified, only those roles whose names match the pattern are listed. If the form `\du+` is used, additional information is shown about each role; currently this adds the comment for each role.

\dx[+] [extension_pattern] Lists installed extensions. If a pattern is specified, only those extensions whose names match the pattern are listed. If the form `\dx+` is used, all of the objects belonging to each matching extension are listed.

\dy[+] [pattern] Lists event triggers. If a pattern is specified, only those triggers whose names match the pattern are listed. If `+` is appended to the command name, each object is listed with its associated description.

\dy[+] [pattern] Lists event triggers. If a pattern is specified, only those triggers whose names match the pattern are listed. If `+` is appended to the command name, each object is listed with its associated description.

> **Note** WarehousePG does not support user-defined triggers.

\e | \edit [filename] [line_number] If filename is specified, the file is edited; after the editor exits, its content is copied back to the query buffer. If no filename is given, the current query buffer is copied to a temporary file which is then edited in the same fashion.

The new query buffer is then re-parsed according to the normal rules of `psql`, where the whole buffer is treated as a single line. (Thus you cannot make scripts this way. Use `\i` for that.) This means also that if the query ends with (or rather contains) a semicolon, it is immediately run. In other cases it will merely wait in the query buffer; type semicolon or `\g` to send it, or `\r` to cancel.

If a line number is specified, `psql` will position the cursor on the specified line of the file or query buffer. Note that if a single all-digits argument is given, `psql` assumes it is a line number, not a file name.

See Environment for information about configuring and customizing your editor.

\echo text [...] Prints the arguments to the standard output, separated by one space and followed by a newline. This can be useful to intersperse information in the output of scripts. If the first argument is an unquoted `-n`, the trailing newline is not written.

> **Note** If you use the `\o` command to redirect your query output you might wish to use `\qecho` instead of this command.

\ef [function_description [line_number]] This command fetches and edits the definition of the named function, in the form of a `CREATE OR REPLACE FUNCTION` command. Editing is done in the same way as for `\edit`. After the editor exits, the updated command waits in the query buffer; type semicolon or `\g` to send it, or `\r` to cancel.

The target function can be specified by name alone, or by name and arguments, for example `foo(integer, text)`. The argument types must be given if there is more than one function with the same name.

If no function is specified, a blank `CREATE FUNCTION` template is presented for editing.

If a line number is specified, `psql` will position the cursor on the specified line of the function body. (Note that the function body typically does not begin on the first line of the file.)

See Environment for information about configuring and customizing your editor.

\encoding [encoding] Sets the client character set encoding. Without an argument, this command shows the current encoding.

\f [field_separator_string] Sets the field separator for unaligned query output. The default is the vertical bar (`|`). See also `\pset` for a generic way of setting output options.

\g [filename] \g [| command] Sends the current query input buffer to the server, and optionally stores the query's output in filename or pipes the output to the shell command command. The file or command is written to only if the query successfully returns zero or more tuples, not if the query fails or is a non-data-returning SQL command.

A bare `\g` is essentially equivalent to a semi-colon. A `\g` with argument is a one-shot alternative to the `\o` command.

\gset [prefix] Sends the current query input buffer to the server and stores the query's output into `psql` variables. The query to be run must return exactly one row. Each column of the row is stored into a separate variable, named the same as the column. For example:

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```
=> SELECT 'hello' AS var1, 10 AS var2;
-> \gset
=> \echo :var1 :var2
hello 10

```

If you specify a prefix, that string is prepended to the query's column names to create the variable names to use:

```
=> SELECT 'hello' AS var1, 10 AS var2;
-> \gset result_
=> \echo :result_var1 :result_var2
hello 10
```

If a column result is NULL, the corresponding variable is unset rather than being set.

If the query fails or does not return one row, no variables are changed.

\h | \help [sql_command] Gives syntax help on the specified SQL command. If a command is not specified, then `psql` will list all the commands for which syntax help is available. If command is an asterisk (`*`) then syntax help on all SQL commands is shown. To simplify typing, commands that consist of several words do not have to be quoted.

\H | \html Turns on HTML query output format. If the HTML format is already on, it is switched back to the default aligned text format. This command is for compatibility and convenience, but see `\pset` about setting other output options.

\i | \include filename Reads input from the file filename and runs it as though it had been typed on the keyboard.

If filename is `-` (hyphen), then standard input is read until an EOF indication or `\q` meta-command. This can be used to intersperse interactive input with input from files. Note that Readline behavior will be used only if it is active at the outermost level.

If you want to see the lines on the screen as they are read you must set the variable `ECHO` to `all`.

\ir | \include_relative filename The `\ir` command is similar to `\i`, but resolves relative file names differently. When running in interactive mode, the two commands behave identically. However, when invoked from a script, `\ir` interprets file names relative to the directory in which the script is located, rather than the current working directory.

\l[+] | \list[+] [pattern] List the databases in the server and show their names, owners, character set encodings, and access privileges. If a pattern is specified, only databases whose names match the pattern are listed. If `+` is appended to the command name, database sizes, default tablespaces, and descriptions are also displayed. (Size information is only available for databases that the current user can connect to.)

\lo_export loid filename Reads the large object with OID loid from the database and writes it to filename. Note that this is subtly different from the server function `lo_export`, which acts with the permissions of the user that the database server runs as and on the server's file system. Use `\lo_list` to find out the large object's OID.

```
> **Note** WarehousePG does not support the PostgreSQL [large object facility](https://www.postgresql.org/docs/12/largeobjects.html) for streaming user data that
is stored in large-object structures.
```

\lo_import large_object_filename [comment] Stores the file into a large object. Optionally, it associates the given comment with the object. Example:

```
mydb=> \lo_import '/home/gpadmin/pictures/photo.xcf' 'a
picture of me'
lo_import 152801
```

The response indicates that the large object received object ID 152801 which one ought to remember if one wants to access the object ever again. For that reason it is recommended to always associate a human-readable comment with every object. Those can then be seen with the `\lo_list` command. Note that this command is subtly different from the server-side `lo_import` because it acts as the local user on the local file system, rather than the server's user and file system.

> **Note** WarehousePG does not support the PostgreSQL large object facility for streaming user data that is stored in large-object structures.

\lo_list Shows a list of all large objects currently stored in the database, along with any comments provided for them.

```
> **Note** WarehousePG does not support the PostgreSQL [large object facility](https://www.postgresql.org/docs/12/largeobjects.html) for streaming user data that
is stored in large-object structures.
```

\lo_unlink largeobject_oid Deletes the large object of the specified OID from the database. Use `\lo_list` to find out the large object's OID.

```
> **Note** WarehousePG does not support the PostgreSQL [large object facility](https://www.postgresql.org/docs/12/largeobjects.html) for streaming user data that
is stored in large-object structures.
```

\o | \out [filename] \o | \out [`|` command] Saves future query results to the file filename or pipes future results to the shell command command. If no argument is specified, the query output is reset to the standard output. Query results include all tables, command responses, and notices obtained from the database server, as well as output of various backslash commands that query the database (such as `\d`), but not error messages. To intersperse text output in between query results, use `\qecho`.

\p Print the current query buffer to the standard output.

\password [username] Changes the password of the specified user (by default, the current user). This command prompts for the new password, encrypts it, and sends it to the server as an `ALTER ROLE` command. This makes sure that the new password does not appear in cleartext in the command history, the server log, or elsewhere.

\prompt [text] name Prompts the user to supply text, which is assigned to the variable name. An optional prompt string, text, can be specified. (For multiword prompts, surround the text with single quotes.)

By default, `\prompt` uses the terminal for input and output. However, if the `-f` command line switch was used, `\prompt` uses standard input and standard output.

\pset [print_option [value]] This command sets options affecting the output of query result tables. print_option describes which option is to be set. The semantics of value vary depending on the selected option. For some options, omitting value causes the option to be toggled or unset, as described under the particular option. If no such behavior is mentioned, then omitting value just results in the current setting being displayed.

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`\pset` without any arguments displays the current status of all printing options.

Adjustable printing options are:

```
-   **`border`** - The value must be a number. In general, the higher the number the more borders and lines the tables will have, but this depends on the
particular format. In HTML format, this will translate directly into the `border=...` attribute; in the other formats only values `0` \(no border\), `1` \
(internal dividing lines\), and `2` \(table frame\) make sense. `latex` and `latex-longtable` also support a `border` value of 3 which adds a dividing line
between each row.
-   **`columns`** - Sets the target width for the `wrapped` format, and also the width limit for determining whether output is wide enough to require the pager or
switch to the vertical display in expanded auto mode. The default is zero. Zero causes the target width to be controlled by the environment variable `COLUMNS`, or
the detected screen width if `COLUMNS` is not set. In addition, if `columns` is zero then the wrapped format affects screen output only. If columns is nonzero
then file and pipe output is wrapped to that width as well.
    <br/><br/>After setting the target width, use the command `\pset format wrapped` to enable the wrapped format.

-   **`expanded`** \| **`x`** - If value is specified it must be either `on` or `off`, which will activate or deactivate expanded mode, or `auto`. If value is
omitted the command toggles between the `on` and `off` settings. When expanded mode is enabled, query results are displayed in two columns, with the column name
on the left and the data on the right. This mode is useful if the data wouldn't fit on the screen in the normal "horizontal" mode. In the `auto` setting, the
expanded mode is used whenever the query output is wider than the screen, otherwise the regular mode is used. The `auto` setting is only effective in the aligned
and wrapped formats. In other formats, it always behaves as if the expanded mode is `off`.
-   **`fieldsep`** - Specifies the field separator to be used in unaligned output mode. That way one can create, for example, tab- or comma-separated output,
which other programs might prefer. To set a tab as field separator, type `\pset fieldsep '\t'`. The default field separator is `'|'` \(a vertical bar\).
-   **`fieldsep_zero`** - Sets the field separator to use in unaligned output format to a zero byte.
-   **`footer`** - If value is specified it must be either `on` or `off` which will activate or deactivate display of the table footer \(the \(n rows\) count\).
If value is omitted the command toggles footer display on or off.
-   **`format`** - Sets the output format to one of `unaligned`, `aligned`, `html`, `latex` \(uses `tabular`\), `latex-longtable`, `troff-ms`, or `wrapped`.
Unique abbreviations are allowed.
    **`unaligned`** format writes all columns of a row on one line, separated by the currently active field separator. This is useful for creating output that
might be intended to be read in by other programs \(for example, tab-separated or comma-separated format\).
    <br/><br/>**`aligned`** format is the standard, human-readable, nicely formatted text output; this is the default.
    <br/><br/>The **`html`**, **`latex`**, **`latex-longtable`**, and **`troff-ms`** formats put out tables that are intended to be included in documents using
the respective mark-up language. They are not complete documents! \(This might not be so dramatic in HTML, but in LaTeX you must have a complete document wrapper.
`latex-longtable` also requires the LaTeX `longtable` and `booktabs` packages.\)
    <br/><br/>The **`wrapped`** format is like `aligned`, but wraps wide data values across lines to make the output fit in the target column width. The target
width is determined as described under the `columns` option. Note that `psql` does not attempt to wrap column header titles; the `wrapped` format behaves the same
as `aligned` if the total width needed for column headers exceeds the target.

-   **`linestyle`** \[**`unicode`** \| **`ascii`** \| **`old-ascii`**\] - Sets the border line drawing style to one of unicode, ascii, or old-ascii. Unique
abbreviations, including one letter, are allowed for the three styles. The default setting is `ascii`. This option only affects the `aligned` and `wrapped` output
formats.
    <br/><br/>**`ascii`** - uses plain ASCII characters. Newlines in data are shown using a `+` symbol in the right-hand margin. When the wrapped format wraps
data from one line to the next without a newline character, a dot \(`.`\) is shown in the right-hand margin of the first line, and again in the left-hand margin
of the following line.
    <br/><br/>**`old-ascii`** - style uses plain ASCII characters, using the formatting style used in PostgreSQL 8.4 and earlier. Newlines in data are shown using
a `:` symbol in place of the left-hand column separator. When the data is wrapped from one line to the next without a newline character, a `;` symbol is used in
place of the left-hand column separator.
    <br/><br/>**`unicode`** - style uses Unicode box-drawing characters. Newlines in data are shown using a carriage return symbol in the right-hand margin. When
the data is wrapped from one line to the next without a newline character, an ellipsis symbol is shown in the right-hand margin of the first line, and again in
the left-hand margin of the following line.
    <br/><br/>When the `border` setting is greater than zero, this option also determines the characters with which the border lines are drawn. Plain ASCII
characters work everywhere, but Unicode characters look nicer on displays that recognize them.

-   **`null 'string'`** - The second argument is a string to print whenever a column is null. The default is to print nothing, which can easily be mistaken for an
empty string. For example, one might prefer `\pset null '(null)'`.
-   **`numericlocale`** - If value is specified it must be either `on` or `off` which will activate or deactivate display of a locale-specific character to
separate groups of digits to the left of the decimal marker. If value is omitted the command toggles between regular and locale-specific numeric output.
-   **`pager`** - Controls the use of a pager for query and `psql` help output. If the environment variable `PAGER` is set, the output is piped to the specified
program. Otherwise a platform-dependent default \(such as `more`\) is used. When `off`, the pager program is not used. When `on`, the pager is used only when
appropriate, i.e. when the output is to a terminal and will not fit on the screen. Pager can also be set to `always`, which causes the pager to be used for all
terminal output regardless of whether it fits on the screen. `\pset pager` without a value toggles pager use on and off.
-   **`recordsep`** - Specifies the record \(line\) separator to use in unaligned output mode. The default is a newline character.
-   **`recordsep_zero`** - Sets the record separator to use in unaligned output format to a zero byte.
-   **`tableattr`** \| **`T`** \[text\] - In HTML format, this specifies attributes to be placed inside the HTML `table` tag. This could for example be
`cellpadding` or `bgcolor`. Note that you probably don't want to specify `border` here, as that is already taken care of by `\pset border`. If no value is given,
the table attributes are unset.
    <br/><br/>In `latex-longtable` format, this controls the proportional width of each column containing a left-aligned data type. It is specified as a
whitespace-separated list of values, e.g. `'0.2 0.2 0.6'`. Unspecified output columns use the last specified value.

-   **`title`** \[text\] - Sets the table title for any subsequently printed tables. This can be used to give your output descriptive tags. If no value is given,
the title is unset.
-   **`tuples_only`** \| **`t`** \[novalue \| on \| off\] - If value is specified, it must be either `on` or `off` which will activate or deactivate tuples-only
mode. If value is omitted the command toggles between regular and tuples-only output. Regular output includes extra information such as column headers, titles,
and various footers. In tuples-only mode, only actual table data is shown. The `\t` command is equivalent to `\pset``tuples_only` and is provided for convenience.

**Tip:**

There are various shortcut commands for `\pset`. See `\a`, `\C`, `\f`, `\H`, `\t`, `\T`, and `\x`.
```

\q | \quit Quits the `psql` program. In a script file, only execution of that script is terminated.

\qecho text [...] This command is identical to `\echo` except that the output will be written to the query output channel, as set by `\o`.

\r | \reset Resets (clears) the query buffer.

\s [filename] Print `psql`'s command line history to `filename`. If `filename` is omitted, the history is written to the standard output (using the pager if appropriate). This command is not available if `psql` was built without `Readline` support.

\set [name [value [...]]] Sets the `psql` variable name to value, or if more than one value is given, to the concatenation of all of them. If only one argument is given, the variable is just set with an empty value. To unset a variable, use the `\unset` command.

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`\set` without any arguments displays the names and values of all currently-set `psql` variables.

Valid variable names can contain characters, digits, and underscores. See "Variables" in Advanced Features. Variable names are case-sensitive.

Although you are welcome to set any variable to anything you want, `psql` treats several variables as special. They are documented in the topic about variables.

This command is unrelated to the SQL command SET.

\setenv name [value] Sets the environment variable name to value, or if the value is not supplied, unsets the environment variable. Example:

```
testdb=> \setenv PAGER less
testdb=> \setenv LESS -imx4F
```

\sf[+] function_description This command fetches and shows the definition of the named function, in the form of a `CREATE OR REPLACE FUNCTION` command. The definition is printed to the current query output channel, as set by `\o`.

The target function can be specified by name alone, or by name and arguments, for example `foo(integer, text)`. The argument types must be given if there is more than one function of the same name.

If `+` is appended to the command name, then the output lines are numbered, with the first line of the function body being line 1.

\t [novalue | on | off] The `\t` command by itself toggles a display of output column name headings and row count footer. The values `on` and `off` set the tuples display, regardless of the current setting. This command is equivalent to `\pset tuples_only` and is provided for convenience.

\T table_options Specifies attributes to be placed within the `table` tag in HTML output format. This command is equivalent to `\pset tableattr table_options`

\timing [novalue | on | off] Without a parameter, toggles a display of how long each SQL statement takes, in milliseconds. The values `on` and `off` set the time display, regardless of the current setting.

\unset name Unsets (deletes) the `psql` variable name.

\w | \write filename \w | \write `|` command Outputs the current query buffer to the file filename or pipes it to the shell command command.

\watch [seconds] Repeatedly runs the current query buffer (like `\g`) until interrupted or the query fails. Wait the specified number of seconds (default 2) between executions.

\x [on | off | auto] Sets or toggles expanded table formatting mode. As such it is equivalent to `\pset expanded`.

\z [pattern] Lists tables, views, and sequences with their associated access privileges. If a pattern is specified, only tables, views and sequences whose names match the pattern are listed. This is an alias for `\dp`.

\! [command] Escapes to a separate shell or runs the shell command command. The arguments are not further interpreted; the shell will see them as-is. In particular, the variable substitution rules and backslash escapes do not apply.

\? Shows help information about the `psql` backslash commands.

Patterns

The various `\d` commands accept a pattern parameter to specify the object name(s) to be displayed. In the simplest case, a pattern is just the exact name of the object. The characters within a pattern are normally folded to lower case, just as in SQL names; for example, `\dt FOO` will display the table named `foo`. As in SQL names, placing double quotes around a pattern stops folding to lower case. Should you need to include an actual double quote character in a pattern, write it as a pair of double quotes within a double-quote sequence; again this is in accord with the rules for SQL quoted identifiers. For example, `\dt "FOO""BAR"` will display the table named `FOO"BAR` (not `foo"bar`). Unlike the normal rules for SQL names, you can put double quotes around just part of a pattern, for instance `\dt FOO"FOO"BAR` will display the table named `fooFOObar`.

Within a pattern, `*` matches any sequence of characters (including no characters) and `?` matches any single character. (This notation is comparable to UNIX shell file name patterns.) For example, `\dt int*` displays all tables whose names begin with `int`. But within double quotes, `*` and `?` lose these special meanings and are just matched literally.

A pattern that contains a dot (`.`) is interpreted as a schema name pattern followed by an object name pattern. For example, `\dt foo*.bar*` displays all tables whose table name starts with `bar` that are in schemas whose schema name starts with `foo`. When no dot appears, then the pattern matches only objects that are visible in the current schema search path. Again, a dot within double quotes loses its special meaning and is matched literally.

Advanced users can use regular-expression notations. All regular expression special characters work as specified in thePostgreSQL documentation on regular expressions, except for `.` which is taken as a separator as mentioned above, `*` which is translated to the regular-expression notation `.*`, and `?` which is translated to `.`. You can emulate these pattern characters at need by writing `?` for `.`, `(R+|)` for `R*`, or `(R|)` for `R?`. Remember that the pattern must match the whole name, unlike the usual interpretation of regular expressions; write `*` at the beginning and/or end if you don't wish the pattern to be anchored. Note that within double quotes, all regular expression special characters lose their special meanings and are matched literally. Also, the regular expression special characters are matched literally in operator name patterns (such as the argument of `\do`).

Whenever the pattern parameter is omitted completely, the `\d` commands display all objects that are visible in the current schema search path – this is equivalent to using the pattern `*.`. To see all objects in the database, use the pattern `*.*.`

Advanced Features

Variables

`psql` provides variable substitution features similar to common UNIX command shells. Variables are simply name/value pairs, where the value can be any string of any length. The name must consist of letters (including non-Latin letters), digits, and underscores.

To set a variable, use the psql meta-command `\set`. For example,

```
testdb=> \set foo bar
```

sets the variable `foo` to the value `bar`. To retrieve the content of the variable, precede the name with a colon, for example:

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```
testdb=> \echo :foo
bar
```

This works in both regular SQL commands and meta-commands; there is more detail in SQL Interpolation.

If you call `\set` without a second argument, the variable is set, with an empty string as value. To unset (i.e., delete) a variable, use the command `\unset`. To show the values of all variables, call `\set` without any argument.

> **Note** The arguments of `\set` are subject to the same substitution rules as with other commands. Thus you can construct interesting references such as `\set :foo 'something'` and get 'soft links' or 'variable variables' of Perl or PHP fame, respectively. Unfortunately, there is no way to do anything useful with these constructs. On the other hand, `\set bar :foo` is a perfectly valid way to copy a variable.

A number of these variables are treated specially by `psql`. They represent certain option settings that can be changed at run time by altering the value of the variable, or in some cases represent changeable state of `psql`. Although you can use these variables for other purposes, this is not recommended, as the program behavior might grow really strange really quickly. By convention, all specially treated variables' names consist of all upper-case ASCII letters (and possibly digits and underscores). To ensure maximum compatibility in the future, avoid using such variable names for your own purposes. A list of all specially treated variables follows.

AUTOCOMMIT When on (the default), each SQL command is automatically committed upon successful completion. To postpone commit in this mode, you must enter a `BEGIN` or `START TRANSACTION` SQL command. When off or unset, SQL commands are not committed until you explicitly issue `COMMIT` or `END`. The autocommit-on mode works by issuing an implicit `BEGIN` for you, just before any command that is not already in a transaction block and is not itself a `BEGIN` or other transaction-control command, nor a command that cannot be run inside a transaction block (such as `VACUUM`).

In autocommit-off mode, you must explicitly abandon any failed transaction by entering `ABORT` or `ROLLBACK`. Also keep in mind that if you exit the session without committing, your work will be lost.

The autocommit-on mode is PostgreSQL's traditional behavior, but autocommit-off is closer to the SQL spec. If you prefer autocommit-off, you may wish to set it in your `~/.psqlrc` file.

COMP_KEYWORD_CASE Determines which letter case to use when completing an SQL key word. If set to `lower` or `upper`, the completed word will be in lower or upper case, respectively. If set to `preserve-lower` or `preserve-upper` (the default), the completed word will be in the case of the word already entered, but words being completed without anything entered will be in lower or upper case, respectively.

DBNAME The name of the database you are currently connected to. This is set every time you connect to a database (including program start-up), but can be unset.

ECHO If set to `all`, all nonempty input lines are printed to standard output as they are read. (This does not apply to lines read interactively.) To select this behavior on program start-up, use the switch `-a`. If set to queries, `psql` prints each query to standard output as it is sent to the server. The switch for this is `-e`.

ECHO_HIDDEN When this variable is set to `on` and a backslash command queries the database, the query is first shown. This feature helps you to study WarehousePG internals and provide similar functionality in your own programs. (To select this behavior on program start-up, use the switch `-E`.) If you set the variable to the value `noexec`, the queries are just shown but are not actually sent to the server and run.

ENCODING The current client character set encoding.

FETCH_COUNT If this variable is set to an integer value > 0, the results of `SELECT` queries are fetched and displayed in groups of that many rows, rather than the default behavior of collecting the entire result set before display. Therefore only a limited amount of memory is used, regardless of the size of the result set. Settings of 100 to 1000 are commonly used when enabling this feature. Keep in mind that when using this feature, a query may fail after having already displayed some rows.

Although you can use any output format with this feature, the default aligned format tends to look bad because each group of `FETCH_COUNT` rows will be formatted separately, leading to varying column widths across the row groups. The other output formats work better.

HISTCONTROL If this variable is set to `ignorespace`, lines which begin with a space are not entered into the history list. If set to a value of `ignoredups`, lines matching the previous history line are not entered. A value of `ignoreboth` combines the two options. If unset, or if set to any other value than those above, all lines read in interactive mode are saved on the history list.

HISTFILE The file name that will be used to store the history list. The default value is `~/.psql_history`. For example, putting

```
```
\set HISTFILE ~/.psql_history- :DBNAME
```
```

in `~/.psqlrc` will cause `psql` to maintain a separate history for each database.

HISTSIZE The number of commands to store in the command history. The default value is 500.

HOST The database server host you are currently connected to. This is set every time you connect to a database (including program start-up), but can be unset.

IGNOREEOF If unset, sending an `EOF` character (usually `CTRL+D`) to an interactive session of `psql` will terminate the application. If set to a numeric value, that many `EOF` characters are ignored before the application terminates. If the variable is set but has no numeric value, the default is `10`.

LASTOID The value of the last affected OID, as returned from an `INSERT` or `lo_import` command. This variable is only guaranteed to be valid until after the result of the next SQL command has been displayed.

ON_ERROR_ROLLBACK When set to `on`, if a statement in a transaction block generates an error, the error is ignored and the transaction continues. When set to `interactive`, such errors are only ignored in interactive sessions, and not when reading script files. When unset or set to `off`, a statement in a transaction block that generates an error cancels the entire transaction. The error rollback mode works by issuing an implicit `SAVEPOINT` for you, just before each command that is in a transaction block, and rolls back to the savepoint on error.

ON_ERROR_STOP By default, command processing continues after an error. When this variable is set to `on`, processing will instead stop immediately. In interactive mode, `psql` will return to the command prompt; otherwise, `psql` will exit, returning error code 3 to distinguish this case from fatal error conditions, which are reported using error code 1. In either case, any currently running scripts (the top-level script, if any, and any other scripts which it may have in invoked) will be terminated immediately. If the top-level command string contained multiple SQL commands, processing will stop with the current command.

PORT The database server port to which you are currently connected. This is set every time you connect to a database (including program start-up), but can be unset.

PROMPT1 PROMPT2 PROMPT3 These specify what the prompts `psql` issues should look like. See "Prompting".

QUIET Setting this variable to `on` is equivalent to the command line option `-q`. It is not very useful in interactive mode.

SINGLELINE This variable is equivalent to the command line option `-S`.

SINGLESTEP Setting this variable to `on` is equivalent to the command line option `-s`.

USER The database user you are currently connected as. This is set every time you connect to a database (including program start-up), but can be unset.

VERBOSITY This variable can be set to the values `default`, `verbose`, or `terse` to control the verbosity of error reports.

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SQL Interpolation

A key feature of `psql` variables is that you can substitute ("interpolate") them into regular SQL statements, as well as the arguments of meta-commands. Furthermore, `psql` provides facilities for ensuring that variable values used as SQL literals and identifiers are properly quoted. The syntax for interpolating a value without any quoting is to prepend the variable name with a colon (`:`). For example,

```
testdb=> \set foo 'my_table'
testdb=> SELECT * FROM :foo;
```

would query the table `my_table`. Note that this may be unsafe: the value of the variable is copied literally, so it can contain unbalanced quotes, or even backslash commands. You must make sure that it makes sense where you put it.

When a value is to be used as an SQL literal or identifier, it is safest to arrange for it to be quoted. To quote the value of a variable as an SQL literal, write a colon followed by the variable name in single quotes. To quote the value as an SQL identifier, write a colon followed by the variable name in double quotes. These constructs deal correctly with quotes and other special characters embedded within the variable value. The previous example would be more safely written this way:

```
testdb=> \set foo 'my_table'
testdb=> SELECT * FROM :"foo";
```

Variable interpolation will not be performed within quoted SQL literals and identifiers. Therefore, a construction such as `':foo'` doesn't work to produce a quoted literal from a variable's value (and it would be unsafe if it did work, since it wouldn't correctly handle quotes embedded in the value).

One example use of this mechanism is to copy the contents of a file into a table column. First load the file into a variable and then interpolate the variable's value as a quoted string:

```
testdb=> \set content `cat my_file.txt`
testdb=> INSERT INTO my_table VALUES (:'content');
```

(Note that this still won't work if `my_file.txt` contains `NUL` bytes. `psql` does not support embedded `NUL` bytes in variable values.)

Since colons can legally appear in SQL commands, an apparent attempt at interpolation (that is, `:name`, `:'name'`, or `:"name"`) is not replaced unless the named variable is currently set. In any case, you can escape a colon with a backslash to protect it from substitution.

The colon syntax for variables is standard SQL for embedded query languages, such as ECPG. The colon syntaxes for array slices and type casts are WarehousePG extensions, which can sometimes conflict with the standard usage. The colon-quote syntax for escaping a variable's value as an SQL literal or identifier is a `psql` extension.

Prompting

The prompts `psql` issues can be customized to your preference. The three variables `PROMPT1`, `PROMPT2`, and `PROMPT3` contain strings and special escape sequences that describe the appearance of the prompt. Prompt 1 is the normal prompt that is issued when `psql` requests a new command. Prompt 2 is issued when more input is expected during command entry, for example because the command was not terminated with a semicolon or a quote was not closed. Prompt 3 is issued when you are running an SQL `COPY FROM STDIN` command and you need to type in a row value on the terminal.

The value of the selected prompt variable is printed literally, except where a percent sign (`%`) is encountered. Depending on the next character, certain other text is substituted instead. Defined substitutions are:

%M The full host name (with domain name) of the database server, or `[local]` if the connection is over a UNIX domain socket, or `[local:/dir/name]`, if the UNIX domain socket is not at the compiled in default location.

%m The host name of the database server, truncated at the first dot, or `[local]` if the connection is over a UNIX domain socket.

%> The port number at which the database server is listening.

%n The database session user name. (The expansion of this value might change during a database session as the result of the command `SET SESSION AUTHORIZATION`.)

%/ The name of the current database.

%~ Like `%/`, but the output is `~` (tilde) if the database is your default database.

%# If the session user is a database superuser, then a **#**, otherwise a **>**. (The expansion of this value might change during a database session as the result of the command `SET SESSION AUTHORIZATION`.)

%R In prompt 1 normally `=`, but `^` if in single-line mode, or `!` if the session is disconnected from the database (which can happen if `\connect` fails). In prompt 2 `%R` is replaced by a character that depends on why `psql` expects more input: `-` if the command simply wasn't terminated yet, but `*` if there is an unfinished `/* ... */` comment, a single quote if there is an unfinished quoted string, a double quote if there is an unfinished quoted identifier, a dollar sign if there is an unfinished dollar-quoted string, or `(` if there is an unmatched left parenthesis. In prompt 3 `%R` doesn't produce anything.

%x Transaction status: an empty string when not in a transaction block, or***** when in a transaction block, or**!** when in a failed transaction block, or**?** when the transaction state is indeterminate (for example, because there is no connection).

%digits The character with the indicated octal code is substituted.

%:name: The value of the `psql` variable name. See "Variables" in Advanced Features for details.

%`command` The output of command, similar to ordinary back-tick substitution.

%[... %] Prompts may contain terminal control characters which, for example, change the color, background, or style of the prompt text, or change the title of the terminal window. In order for line editing to work properly, these non-printing control characters must be designated as invisible by surrounding them with `%[` and `%]`. Multiple pairs of these may occur within the prompt. For example,

```
testdb=> \set PROMPT1 '%[%033[1;33;40m%]%n@%/%R%[%033[0m%]%#'
```

results in a boldfaced (`1;`) yellow-on-black (`33;40`) prompt on VT100-compatible, color-capable terminals. To insert a percent sign into your prompt, write `%%`. The default prompts are `'%/%R%# '` for prompts 1 and 2, and `'>> '` for prompt 3.

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Command-Line Editing

`psql` uses the `readline` library for convenient line editing and retrieval. The command history is automatically saved when `psql` exits and is reloaded when `psql` starts up. Tab-completion is also supported, although the completion logic makes no claim to be an SQL parser. The queries generated by tab-completion can also interfere with other SQL commands, e.g. `SET TRANSACTION ISOLATION LEVEL`. If for some reason you do not like the tab completion, you can turn it off by putting this in a file named `.inputrc` in your home directory:

```
$if psql
set disable-completion on
$endif
```

Environment

COLUMNS If `\pset columns` is zero, controls the width for the wrapped format and width for determining if wide output requires the pager or should be switched to the vertical format in expanded auto mode.

PAGER If the query results do not fit on the screen, they are piped through this command. Typical values are `more` or `less`. The default is platform-dependent. The use of the pager can be deactivated by setting PAGER to empty, or by using pager-related options of the `\pset` command.

PGDATABASE PGHOST PGPORT PGUSER Default connection parameters.

PSQL_EDITOR EDITOR VISUAL Editor used by the `\e` and `\ef` commands. The variables are examined in the order listed; the first that is set is used.

The built-in default editors are `vi` on Unix systems and `notepad.exe` on Windows systems.

PSQL_EDITOR_LINENUMBER_ARG When `\e` or `\ef` is used with a line number argument, this variable specifies the command-line argument used to pass the starting line number to the user's editor. For editors such as Emacs or `vi`, this is a plus sign. Include a trailing space in the value of the variable if there needs to be space between the option name and the line number. Examples:

```
```
PSQL_EDITOR_LINENUMBER_ARG='+'
PSQL_EDITOR_LINENUMBER_ARG='--line '
```
```

The default is `+` on Unix systems (corresponding to the default editor `vi`, and useful for many other common editors); but there is no default on Windows systems.

PSQL_HISTORY Alternative location for the command history file. Tilde (`~`) expansion is performed.

PSQLRC Alternative location of the user's `.psqlrc` file. Tilde (`~`) expansion is performed.

SHELL Command run by the `\!` command.

TMPDIR Directory for storing temporary files. The default is `/tmp`.

Files

psqlrc and ~/.psqlrc Unless it is passed an `-X` or `-c` option, `psql` attempts to read and run commands from the system-wide startup file (`psqlrc`) and then the user's personal startup file (`~/.psqlrc`), after connecting to the database but before accepting normal commands. These files can be used to set up the client and/or the server to taste, typically with `\set` and `SET` commands.

The system-wide startup file is named `psqlrc` and is sought in the installation's "system configuration" directory, which is most reliably identified by running `pg_config --sysconfdir`. By default this directory will be `../etc/` relative to the directory containing the WarehousePG executables. The name of this directory can be set explicitly via the `PGSYSCONFDIR` environment variable.

The user's personal startup file is named `.psqlrc` and is sought in the invoking user's home directory. On Windows, which lacks such a concept, the personal startup file is named `%APPDATA%\postgresql\psqlrc.conf`. The location of the user's startup file can be set explicitly via the `PSQLRC` environment variable.

Both the system-wide startup file and the user's personal startup file can be made psql-version-specific by appending a dash and the underlying PostgreSQL major or minor release number to the file name, for example `~/.psqlrc-9.4`. The most specific version-matching file will be read in preference to a non-version-specific file.

.psql_history The command-line history is stored in the file `~/.psql_history`, or `%APPDATA%\postgresql\psql_history` on Windows.

The location of the history file can be set explicitly via the `PSQL_HISTORY` environment variable.

Notes

`psql` works best with servers of the same or an older major version. Backslash commands are particularly likely to fail if the server is of a newer version than `psql` itself. However, backslash commands of the `\d` family should work with older server versions, though not necessarily with servers newer than `psql` itself. The general functionality of running SQL commands and displaying query results should also work with servers of a newer major version, but this cannot be guaranteed in all cases.

If you want to use `psql` to connect to several servers of different major versions, it is recommended that you use the newest version of `psql`. Alternatively, you can keep a copy of `psql` from each major version around and be sure to use the version that matches the respective server. But in practice, this additional complication should not be necessary.

Notes for Windows Users

`psql` is built as a console application. Since the Windows console windows use a different encoding than the rest of the system, you must take special care when using 8-bit characters within `psql`. If `psql` detects a problematic console code page, it will warn you at startup. To change the console code page, two things are necessary:

Set the code page by entering:

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```
cmd.exe /c chcp 1252
```

`1252` is a character encoding of the Latin alphabet, used by Microsoft Windows for English and some other Western languages. If you are using Cygwin, you can put this command in `/etc/profile`.

Set the console font to Lucida Console, because the raster font does not work with the ANSI code page.

Examples

Start `psql` in interactive mode:

```
psql -p 54321 -U sally mydatabase
```

In `psql` interactive mode, spread a command over several lines of input. Notice the changing prompt:

```
testdb=> CREATE TABLE my_table (
testdb(>  first integer not null default 0,
testdb(>  second text)
testdb-> ;
CREATE TABLE
```

Look at the table definition:

```
testdb=> \d my_table
            Table "public.my_table"
 Column    |  Type   |      Modifiers
-----------+---------+--------------------
 first     | integer | not null default 0
 second    | text    |
Distributed by: (first)
```

Run `psql` in non-interactive mode by passing in a file containing SQL commands:

```
psql -f /home/gpadmin/test/myscript.sql
```

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7.7.2.37 reindexdb

Rebuilds indexes in a database.

Synopsis

```
reindexdb [<connection-option> ...] [<option> ...] [-S | --schema <schema>] ...
        [-t | --table <table>]
        [-i | --index <index>] ... [<dbname>]

reindexdb [<connection-option> ...] [<option> ...] -a | --all

reindexdb [<connection-option> ...] [<option> ...] -s | --system [<dbname>]

reindexdb -? | --help

reindexdb -V | --version
```

Description

`reindexdb` is a utility for rebuilding indexes in WarehousePG.

`reindexdb` is a wrapper around the SQL command REINDEX. There is no effective difference between reindexing databases via this utility and via other methods for accessing the server.

Options

`reindexdb` accepts the following command-line arguments:

-a --all Reindex all databases.

[-d] dbname [--dbname=]dbname Specifies the name of the database to be reindexed, when `-a` or `--all` is not used. If this is not specified, WarehousePG reads the database name from the environment variable `PGDATABASE`. If that is not set, the user name specified for the connection is used. The dbname can be a connection string. If so, connection string parameters will override any conflicting command line options.

-e --echo Echo the commands that `reindexdb` generates and sends to the server.

-i index --index=index Recreate index only. You can recreate multiple indexes by specifying multiple `-i` switches.

-q --quiet Do not display progress messages.

-s --system Reindex system catalogs only.

-S schema --schema=schema Reindex schema only. You can reindex multiple schemas by specifying multiple `-S` switches.

-t table --table=table Reindex table only. You can reindex multiple tables by specifying multiple `-t` switches.

-v --verbose Print detailed information during processing.

-V --version Print the `reindexdb` version and exit.

-? --help Show help about `reindexdb` command line arguments, and exit.

Connection Options

`reindexdb` also accepts the following command-line arguments for connection parameters:

-h host --host=host Specifies the host name of the machine on which the WarehousePG coordinator database server is running. If not specified, reads from the environment variable `PGHOST` or defaults to localhost.

-p port --port=port Specifies the TCP port on which the WarehousePG coordinator database server is listening for connections. If not specified, reads from the environment variable `PGPORT` or defaults to 5432.

-U username --username=username The database user name to connect as. If not specified, reads from the environment variable `PGUSER` or defaults to the current system user name.

-w --no-password Never issue a password prompt. If the server requires password authentication and a password is not available by other means such as a `.pgpass` file, the connection attempt will fail. This option can be useful in batch jobs and scripts where no user is present to enter a password.

-W --password Force `reindexdb` to prompt for a password before connecting to a database. This option is never essential, since `reindexdb` automatically prompts for a password if the server demands password authentication. However, `reindexdb` will waste a connection attempt finding out that the server wants a password. In some cases it is worth typing `-W` to avoid the extra connection attempt.

--maintenance-db=dbname Specifies the name of the database to connect to discover what other databases should be reindexed, when `-a` or `--all` is used. If not specified, the `postgres` database will be used, and if that does not exist, `template1` will be used. This can be a connection. If so, connection string parameters will override any conflicting command line options. Also, connection string parameters other than the database name itself will be re-used when connecting to other databases.

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Notes

`reindexdb` causes locking of system catalog tables, which could affect currently running queries. To avoid disrupting ongoing business operations, schedule the `reindexb` operation during a period of low activity.

`reindexdb` might need to connect several times to the coordinator server, asking for a password each time. It is convenient to have a `~/.pgpass` file in such cases.

Environment

PGDATABASE PGHOST PGPORT PGUSER Default connection parameters.

PG_COLOR Specifies whether to use color in diagnostic messages. Possible values are `always`, `auto`, and `never`.

This utility, like most other WarehousePG utilities, also uses the environment variables supported by `libpq`.

Diagnostics

In case of difficulty, see REINDEX and psql for discussions of potential problems and error messages. The database server must be running at the targeted host. Also, any default connection settings and environment variables used by the `libpq` front-end library will apply.

Notes

`reindexdb` might need to connect several times to the WarehousePG server, asking for a password each time. It is convenient to have a `~/.pgpass` file in such cases.

Examples

To reindex the database named `mydb`:

```
reindexdb mydb
```

To reindex the table `foo` and the index `bar` in a database named `abcd`:

```
reindexdb --table=foo --index=bar abcd
```

See Also

REINDEX

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7.7.2.38 vacuumdb

Garbage-collects and analyzes a database.

Synopsis

```
vacuumdb [<connection-option>...] [--full | -f] [--freeze | -F] [--verbose | -v]
    [--analyze | -z] [--analyze-only | -Z] [--disable-page-skipping] [--skip-locked] [--table | -t <table> [( <column> [,...] )] ] [<dbname>]

vacuumdb [<connection-option>...] [--all | -a] [--full | -f] [-F]
    [--verbose | -v] [--analyze | -z]
    [--analyze-only | -Z]
    [--disable-page-skipping]
    [--skip-locked]

vacuumdb -? | --help

vacuumdb -V | --version
```

Description

`vacuumdb` is a utility for cleaning a WarehousePG database. `vacuumdb` will also generate internal statistics used by the WarehousePG query optimizer.

`vacuumdb` is a wrapper around the SQL command `VACUUM`. There is no effective difference between vacuuming databases via this utility and via other methods for accessing the server.

Options

-a | --all Vacuums all databases.

[-d] dbname | [--dbname=]dbname The name of the database to vacuum. If this is not specified and `-a` (or `--all`) is not used, the database name is read from the environment variable `PGDATABASE`. If that is not set, the user name specified for the connection is used.

-e | --echo Echo the commands that `reindexdb` generates and sends to the server.

-f | --full Selects a full vacuum, which may reclaim more space, but takes much longer and exclusively locks the table.

```
> **Caution** A `VACUUM FULL` is not recommended in WarehousePG.
```

-F | --freeze Freeze row transaction information.

-q | --quiet Do not display a response.

-t table [(column)] | --table= table [(column)] Clean or analyze this table only. Column names may be specified only in conjunction with the `--analyze` or `--analyze-all` options. Multiple tables can be vacuumed by writing multiple `-t` switches. If you specify columns, you probably have to escape the parentheses from the shell.

-v | --verbose Print detailed information during processing.

-z | --analyze Collect statistics for use by the query planner.

-Z | --analyze-only Only calculate statistics for use by the query planner (no vacuum).

--disable-page-skipping Disable all page-skipping behavior.

--skip-locked Skip relations that cannot be immediately locked.

-V | --version Print the `vacuumdb` version and exit.

-? | --help Show help about `vacuumdb` command line arguments, and exit.

Connection Options

-h host | --host=host Specifies the host name of the machine on which the WarehousePG coordinator database server is running. If not specified, reads from the environment variable `PGHOST` or defaults to localhost.

-p port | --port=port Specifies the TCP port on which the WarehousePG coordinator database server is listening for connections. If not specified, reads from the environment variable `PGPORT` or defaults to 5432.

-U username | --username=username The database role name to connect as. If not specified, reads from the environment variable `PGUSER` or defaults to the current system user name.

-w | --no-password Never issue a password prompt. If the server requires password authentication and a password is not available by other means such as a `.pgpass` file, the connection attempt will fail. This option can be useful in batch jobs and scripts where no user is present to enter a password.

-W | --password Force a password prompt.

--maintenance-db=dbname Specifies the name of the database to connect to discover what other databases should be vacuumed. If not specified, the `postgres` database will be used, and if that does not exist, `template1` will be used.

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Notes

`vacuumdb` might need to connect several times to the coordinator server, asking for a password each time. It is convenient to have a `~/.pgpass` file in such cases.

Examples

To clean the database `test`:

```
vacuumdb test
```

To clean and analyze a database named `bigdb`:

```
vacuumdb --analyze bigdb
```

To clean a single table `foo` in a database named `mydb`, and analyze a single column `bar` of the table. Note the quotes around the table and column names to escape the parentheses from the shell:

```
vacuumdb --analyze --verbose --table 'foo(bar)' mydb
```

See Also

VACUUM, ANALYZE

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7.7.2.39 pgbouncer

Manages database connection pools.

Synopsis

```
pgbouncer [OPTION ...] <pgbouncer.ini>

  OPTION
    [ -d | --daemon ]
    [ -R | --reboot ]
    [ -q | --quiet ]
    [ -v | --verbose ]
    [ {-u | --user}=username ]

pgbouncer [ -V | --version ] | [ -h | --help ]
```

Description

PgBouncer is a light-weight connection pool manager for WarehousePG and PostgreSQL databases. PgBouncer maintains a pool of connections for each database user and database combination. PgBouncer either creates a new database connection for the client or reuses an existing pooled connection for the same user and database. When the client disconnects, PgBouncer returns the connection to the pool for re-use.

PgBouncer supports the standard connection interface shared by PostgreSQL and WarehousePG. The WarehousePG client application (for example, `psql`) should connect to the host and port on which PgBouncer is running rather than directly to the WarehousePG coordinator host and port.

You configure PgBouncer and its access to WarehousePG via a configuration file. You provide the configuration file name, usually `<pgbouncer.ini>`, when you run the `pgbouncer` command. This file provides location information for WarehousePGs. The `pgbouncer.ini` file also specifies process, connection pool, authorized users, and authentication configuration for PgBouncer, among other configuration options.

By default, the `pgbouncer` process runs as a foreground process. You can optionally start `pgbouncer` as a background (daemon) process with the `-d` option.

The `pgbouncer` process is owned by the operating system user that starts the process. You can optionally specify a different user name under which to start `pgbouncer`.

PgBouncer includes a `psql`-like administration console. Authorized users can connect to a virtual database to monitor and manage PgBouncer. You can manage a PgBouncer daemon process via the admin console. You can also use the console to update and reload the PgBouncer configuration at runtime without stopping and restarting the process.

For additional information about PgBouncer, refer to the PgBouncer FAQ.

Options

-d | --daemon Run PgBouncer as a daemon (a background process). The default start-up mode is to run as a foreground process.

In daemon mode, setting `pidfile` as well as `logfile` or `syslog` is required. No log messages will be written to `stderr` after going into the background.

To stop a PgBouncer process that was started as a daemon, issue the `SHUTDOWN` command from the PgBouncer administration console.

-R | --reboot Restart PgBouncer using the specified command line arguments. That means connecting to the running process, loading the open sockets from it, and then using them. If there is no active process, boot normally. Non-TLS connections to databases are maintained during restart; TLS connections are dropped.

To restart PgBouncer as a daemon, specify the options `-Rd`.

```
>  **Note** This option is deprecated. Instead, use a rolling restart with multiple Pgbouncer processes listening on the same port using `so_reuseport` instead.

> **Note** Restart is available only if the operating system supports Unix sockets and the PgBouncer `unix_socket_dir` configuration is not deactivated.
```

-q | --quiet Run quietly. Do not log to `stderr`. This does not affect logging verbosity, only that `stderr` is not to be used. For use in `init.d` scripts.

-v | --verbose Increase message verbosity. Can be specified multiple times.

{-u | --user=} \<username> Assume the identity of username on PgBouncer process start-up.

-V | --version Show the version and exit.

-h | --help Show the command help message and exit.

See Also

pgbouncer.ini, pgbouncer-admin

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7.7.2.40 pgbouncer-admin

PgBouncer Administration Console.

Synopsis

```
psql -p <port> pgbouncer
```

Description

The PgBouncer Administration Console is available via `psql`. Connect to the PgBouncer `<port>` and the virtual database named `pgbouncer` to log in to the console.

Users listed in the `pgbouncer.ini` configuration parameters `admin_users` and `stats_users` have privileges to log in to the PgBouncer Administration Console. When `auth_type=any`, then any user is allowed in as a stats_user.

Additionally, the user name `pgbouncer` is allowed to log in without password when the login comes via the Unix socket and the client has same Unix user UID as the running process.

The admin console currently only supports the simple query protocol. Some drivers use the extended query protocol for all commands; these drivers will not work for this console.

You can control connections between PgBouncer and WarehousePG from the console. You can also set PgBouncer configuration parameters.

Options

-p \<port> The PgBouncer port number.

Command Syntax

```
pgbouncer=# SHOW help;
NOTICE:  Console usage
DETAIL:
  SHOW HELP|CONFIG|DATABASES|POOLS|CLIENTS|SERVERS|USERS|VERSION
  SHOW PEERS|PEER_POOLS
  SHOW FDS|SOCKETS|ACTIVE_SOCKETS|LISTS|MEM|STATE
  SHOW DNS_HOSTS|DNS_ZONES
  SHOW STATS|STATS_TOTALS|STATS_AVERAGES|TOTALS
  SET key = arg
  RELOAD
  PAUSE [<db>]
  RESUME [<db>]
  DISABLE <db>
  ENABLE <db>
  RECONNECT [<db>]
  KILL <db>
  SUSPEND
  SHUTDOWN
  WAIT_CLOSE [<db>]
```

Administration Commands

The following PgBouncer administration commands control the running `pgbouncer` process.

PAUSE [\<db>] If no database is specified, PgBouncer tries to disconnect from all servers, first waiting for all queries to be released according to the server pool's pooling mode (in transaction pooling mode, the transaction must complete, in statement mode, the statement must complete, and in session pooling mode the client must disconnect). The command will not return before all queries are finished. This command is to be used to prepare to restart the database.

If a database name is specified, PgBouncer pauses only that database.

New client connections to a paused database will wait until a `RESUME` command is invoked.

DISABLE \<db> Reject all new client connections on the database.

ENABLE \<db> Allow new client connections after a previous `DISABLE` command.

RECONNECT Close each open server connection for the given database, or all databases, after it is released (according to the pooling mode), even if its lifetime is not up yet. New server connections can be made immediately and will connect as necessary according to the pool size settings.

This command is useful when the server connection setup has changed, for example to perform a gradual switchover to a new server. It is not necessary to run this command when the connection string in `pgbouncer.ini` has been changed and reloaded (see `RELOAD`) or when DNS resolution has changed, because then the equivalent of this command will be run automatically. This command is only necessary if something downstream of PgBouncer routes the connections.

After this command is run, there could be an extended period where some server connections go to an old destination and some server connections go to a new destination. This is likely only sensible when switching read-only traffic between read-only replicas, or when switching between nodes of a multimaster replication setup. If all connections need to be switched at the same time, `PAUSE` is recommended instead. To close server connections without waiting (for example, in emergency failover rather than gradual switchover scenarios), also consider `KILL`.

KILL \<db> Immediately drop all client and server connections to the named database.

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New client connections to a killed database will wait until `RESUME` is called.

SUSPEND All socket buffers are flushed and PgBouncer stops listening for data on them. The command will not return before all buffers are empty. To be used when rebooting PgBouncer online.

New client connections to a suspended database will wait until `RESUME` is called.

RESUME [\<db>] Resume work from a previous `KILL`, `PAUSE`, or `SUSPEND` command.

SHUTDOWN The PgBouncer process will exit. To exit from the `psql` command line session, enter `\q`.

RELOAD The PgBouncer process reloads the current configuration file and updates the changeable settings.

PgBouncer notices when a configuration file reload changes the connection parameters of a database definition. An existing server connection to the old destination will be closed when the server connection is next released (according to the pooling mode), and new server connections will immediately use the updated connection parameters

WAIT_CLOSE [\<db>] Wait until all server connections, either of the specified database or of all databases, have cleared the "close_needed" state (see `SHOW SERVERS`). This can be called after a `RECONNECT` or `RELOAD` to wait until the respective configuration change has been fully activated, for example in switchover scripts.

SET key = value Changes the specified configuration setting. See the `SHOW CONFIG;` command.

(Note that this command is run on the PgBouncer admin console and sets PgBouncer settings. A `SET` command run on another database will be passed to the PostgreSQL backend like any other SQL command.)

SHOW Command

The `SHOW <category>` command displays different types of PgBouncer information. You can specify one of the following categories:

- CLIENTS
- CONFIG
- DATABASES
- DNS_HOSTS
- DNS_ZONES
- FDS
- LISTS
- MEM
- POOLS
- PEERS
- PEER_POOLS
- SERVERS
- SOCKETS, ACTIVE_SOCKETS,
- STATS
- STATS_TOTALS
- STATS_AVERAGES
- TOTALS
- USERS
- VERSION

CLIENTS

Column	Description
type	C, for client.
user	Client connected user.
database	Database name.
state	State of the client connection, one of `active`, `waiting`, `active_cancel_req`, or `waiting_cancel_req`.
addr	IP address of client.
port	Port client is connected to.
local_addr	Connection end address on local machine.
local_port	Connection end port on local machine.
connect_time	Timestamp of connect time.
request_time	Timestamp of latest client request.
wait	Current Time waiting in seconds.
wait_us	Microsecond part of the current waiting time.
close_needed	Not used for clients.
ptr	Address of internal object for this connection. Used as unique ID.
link	Address of server connection the client is paired with.
remote_pid	Process ID, if client connects with Unix socket and the OS supports getting it.
tls	A string with TLS connection information, or empty if not using TLS.
application_name	A string containing the `application_name` set by the client for this connection, or empty if not set.
prepared_statements	The amount of prepared statements that the client has prepared.

CONFIG

Show the current PgBouncer configuration settings, one per row, with the following columns:

Column	Description
key	Configuration variable name
value	Configuration value

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Column	Description
default	Configuration default value
changeable	Either `yes` or `no`. Shows whether the variable can be changed while running. If `no`, the variable can be changed only at boot time. Use `SET` to change a variable at run time.

DATABASES

Column	Description
name	Name of configured database entry.
host	Host pgbouncer connects to.
port	Port pgbouncer connects to.
database	Actual database name pgbouncer connects to.
force_user	When user is part of the connection string, the connection between pgbouncer and the database server is forced to the given user, whatever the client user.
pool_size	Maximum number of server connections.
min_pool_size	Minimum number of server connections.
reserve_pool	The maximum number of additional connections for this database.
pool_mode	The database's override `pool_mode` or NULL if the default will be used instead.
max_connections	Maximum number of allowed connections for this database, as set by `max_db_connections`, either globally or per-database.
current_connections	The current number of connections for this database.
paused	Paused/unpaused state of the database. 1 if this database is currently paused, else 0.
disabled	Enabled/disabled state of the database. 1 if this database is currently disabled, else 0.

DNS_HOSTS

Show host names in DNS cache.

Column	Description
hostname	Host name
ttl	How many seconds until next lookup.
addrs	Comma-separated list of addresses.

DNS_ZONES

Show DNS zones in cache.

Column	Description
zonename	Zone name
serial	Current DNS serial number
count	Hostnames belonging to this zone

FDS

`SHOW FDS` is an internal command used for an online restart, for example when upgrading to a new PgBouncer version. It displays a list of file descriptors in use with the internal state attached to them. This command blocks the internal event loop, so it should not be used while PgBouncer is in use.

When the connected user has username "pgbouncer", connects through a Unix socket, and has the same UID as the running process, the actual file descriptors are passed over the connection. This mechanism is used to do an online restart.

Column	Description
fd	File descriptor numeric value.
task	One of `pooler`, `client`, or `server`.
user	User of the connection using the file descriptor.
database	Database of the connection using the file descriptor.
addr	IP address of the connection using the file descriptor, `unix` if a Unix socket is used.
port	Port used by the connection using the file descriptor.
cancel	Cancel key for this connection.
link	File descriptor for corresponding server/client. NULL if idle.

LISTS

Shows the following PgBouncer internal information, in columns (not rows):

Item	Description
databases	Count of databases.
users	Count of users.
pools	Count of pools.
free_clients	Count of free clients.

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Item	Description
used_clients	Count of used clients.
login_clients	Count of clients in `login` state.
free_servers	Count of free servers.
used_servers	Count of used servers.
dns_names	Count of DNS names in the cache.
dns_zones	Count of DNS zones in the cache.
dns_queries	Count of in-flight DNS queries.
dns_pending	not used

MEM

Shows low-level information about the current sizes of various internal memory allocations. The information presented is subject to change.

PEERS

Column	Description
peer_id	ID of the configured peer entry.
host	Host PgBouncer connects to.
port	Port PgBouncer connects to.
pool_size	Maximum number of server connections that can be made to this peer.

PEER_POOLS

A new `peer_pool` entry is made for each configured peer.

Column	Description
Database	ID of the configured peer entry.
cl_active_cancel_req	Client connections that have forwarded query cancellations to the server and are waiting for the server response.
cl_waiting_cancel_req	Client connections that have not forwarded query cancellations to the server yet.
sv_active_cancel	Server connections that are currently forwarding a cancel request.
sv_login	Server connections currently in the process of logging in.

POOLS

A new pool entry is made for each pair of (database, user).

Column	Description
database	Database name.
user	User name.
cl_active	Client connections that are linked to server connection and can process queries.
cl_waiting	Client connections that have sent queries but have not yet got a server connection.
cl_active_cancel_req	Client connections that have forwarded query cancellations to the server and are waiting for the server response.
cl_waiting_cancel_req	Client connections that have not forwarded query cancellations to the server yet.
sv_active	Server connections that are linked to client.
sv_active_cancel	Server connections that are currently forwarding a cancel request.
sv_being_canceled	Servers that normally could become idle but are waiting to do so until all in-flight cancel requests have completed that were sent to cancel a query on this server.
sv_idle	Server connections that are unused and immediately usable for client queries.
sv_used	Server connections that have been idle more than `server_check_delay`. The `server_check_query` query must be run on them before they can be used again.
sv_tested	Server connections that are currently running either `server_reset_query` or `server_check_query`.
sv_login	Server connections currently in the process of logging in.
maxwait	How long the first (oldest) client in the queue has waited, in seconds. If this begins to increase, the current pool of servers does not handle requests quickly enough. The cause may be either an overloaded server or the `pool_size` setting is too small.
maxwait_us	Microsecond part of the maximum waiting time.
pool_mode	The pooling mode in use.

SERVERS

Column	Description
type	S, for server.
user	User name that `pgbouncer` uses to connect to server.
database	Database name.
state	State of the `pgbouncer` server connection, one of `active`, `idle`, `used`, `tested`, or `new`.
addr	IP address of the WarehousePG or PostgreSQL server.
port	Port of the WarehousePG or PostgreSQL server.
local_addr	Connection start address on local machine.

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Column	Description
local_port	Connection start port on local machine.
connect_time	When the connection was made.
request_time	When the last request was issued.
wait	Current waiting time in seconds.
wait_us	Microsecond part of the current waiting time.
close_needed	1 if the connection will be closed as soon as possible, because a configuration file reload or DNS update changed the connection information or `RECONNECT` was issued.
ptr	Address of the internal object for this connection. Used as unique ID.
link	Address of the client connection the server is paired with.
remote_pid	Pid of backend server process. If the connection is made over Unix socket and the OS supports getting process ID info, it is the OS pid. Otherwise it is extracted from the cancel packet the server sent, which should be PID in case server is PostgreSQL, but it is a random number in case server is another PgBouncer.
tls	A string with TLS connection information, or empty if not using TLS.
application_name	A string containing the application_name set on the linked client connection, or empty if this is not set, or if there is no linked connection.
prepared_statements	The amount of prepared statements that are prepared on the server. This number is limited by the max_prepared_statements setting.

SOCKETS, ACTIVE_SOCKETS

Shows low-level information about sockets or only active sockets. This includes the information shown under `SHOW CLIENTS` and `SHOW SERVERS` as well as other more low-level information.

STATS

Shows statistics. In this and related commands, the total figures are since process start, the averages are updated every `stats_period`.

Column	Description
database	Statistics are presented per database.
total_xact_count	Total number of SQL transactions pooled by PgBouncer.
total_query_count	Total number of SQL queries pooled by PgBouncer.
total_received	Total volume in bytes of network traffic received by `pgbouncer`.
total_sent	Total volume in bytes of network traffic sent by `pgbouncer`.
total_xact_time	Total number of microseconds spent by PgBouncer when connected to WarehousePG in a transaction, either idle in transaction or executing queries.
total_query_time	Total number of microseconds spent by `pgbouncer` when actively connected to the database server.
total_wait_time	Time spent (in microseconds) by clients waiting for a server.
avg_xact_count	Average number of transactions per second in the last stat period.
avg_query_count	Average queries per second in the last stats period.
avg_recv	Average received (from clients) bytes per second.
avg_sent	Average sent (to clients) bytes per second.
avg_xact_time	Average transaction duration in microseconds.
avg_query_time	Average query duration in microseconds.
avg_wait_time	Time spent by clients waiting for a server in microseconds (average per second).

STATS_AVERAGES

Subset of `SHOW STATS` showing the average values for selected statistics (`avg_`)

STATS_TOTALS

Subset of `SHOW STATS` showing the total values for selected statistics (`total_`)

TOTALS

Like `SHOW STATS` but aggregated across all databases.

USERS

Column	Description
name	The user name
pool_mode	The user's override pool_mode, or NULL if the default will be used instead.

VERSION

Display PgBouncer version information.

> **Note** This reference documentation is based on the PgBouncer 1.21 documentation.

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Signals

SIGHUP : Reload config. Same as issuing the command `RELOAD` on the console.

SIGINT : Safe shutdown. Same as issuing `PAUSE` and `SHUTDOWN` on the console.

SIGTERM : Immediate shutdown. Same as issuing `SHUTDOWN` on the console.

SIGUSR1 : Same as issuing `PAUSE` on the console.

SIGUSR2 : Same as issuing `RESUME` on the console.

Libevent Settings

From the Libevent documentation:

```
It is possible to disable support for epoll, kqueue, devpoll, poll or select by
setting the environment variable EVENT_NOEPOLL, EVENT_NOKQUEUE, EVENT_NODEVPOLL,
EVENT_NOPOLL or EVENT_NOSELECT, respectively.

By setting the environment variable EVENT_SHOW_METHOD, libevent displays the
kernel notification method that it uses.
```

See Also

pgbouncer, pgbouncer.ini

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7.7.2.41 pgbouncer.ini

PgBouncer configuration file.

Synopsis

```
[databases]
db = ...

[pgbouncer]
...

[users]
...
```

Description

You specify PgBouncer configuration parameters and identify user-specific configuration parameters in a configuration file.

The PgBouncer configuration file (typically named `pgbouncer.ini`) is specified in `.ini` format. Files in `.ini` format are composed of sections, parameters, and values. Section names are enclosed in square brackets, for example, `[<section_name>]`. Parameters and values are specified in `key=value` format. Lines beginning with a semicolon (`;`) or pound sign (`#`) are considered comment lines and are ignored.

The PgBouncer configuration file can contain `%include` directives, which specify another file to read and process. This enables you to split the configuration file into separate parts. For example:

```
%include filename
```

If the filename provided is not an absolute path, the file system location is taken as relative to the current working directory.

The PgBouncer configuration file includes the following sections, described in detail below:

- [databases] Section
- [pgbouncer] Section
- [users] Section
- [peers] Section

[databases] Section

The `[databases]` section contains `key=value` pairs, where the `key` is a database name and the `value` is a `libpq` connect-string list of `key` = `value` pairs. Not all features known from `libpq` can be used (service=, .pgpass), since the actual `libpq` is not used.

A database name can contain characters `[0-9A-Za-z_.-]` without quoting. Names that contain other characters must be quoted with standard SQL identifier quoting:

- Enclose names in double quotes (`" "`).
- Represent a double-quote within an identifier with two consecutive double quote characters.

The database name `*` is the fallback database. PgBouncer uses the value for this key as a connect string for the requested database. Automatically-created database entries such as these are cleaned up if they remain idle longer than the time specified in `autodb_idle_timeout` parameter.

Database Connection Parameters

The following parameters may be included in the `value` to specify the location of the database.

dbname The destination database name.

```
Default: the client-specified database name
```

host The name or IP address of the WarehousePG coordinator host. Host names are resolved at connect time. If DNS returns several results, they are used in a round-robin manner. The DNS result is cached and the `dns_max_ttl` parameter determines when the cache entry expires.

When a host name's resolution changes, any existing server connections are automatically closed when they are released (according to the pooling mode).

If the value begins with `/`, then a Unix socket in the file-system namespace is used. If the value begins with `@`, then a Unix socket in the abstract namespace is used.

You may specify a comma-separated list of host names or addresses. In that case, connections are made in a round-robin manner. If a host list contains host names that in turn resolve via DNS to multiple addresses, the round-robin systems operate independently. Note that in a list, all hosts must be available at all times: There are no mechanisms to skip unreachable hosts or to select only available hosts from a list. Also note that this only affects how the destinations of new connections are chosen. See also the setting `server_round_robin` in the `[pgbouncer]` section for how clients are assigned to already established server connections.

Examples:

```
```
host=localhost
host=127.0.0.1
host=2001:0db8:85a3:0000:0000:8a2e:0370:7334
host=/var/run/postgresql
host=192.168.0.1,192.168.0.2,192.168.0.3
```
```

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Default: not set; the connection is made through a Unix socket

port The WarehousePG coordinator port.

Default: 5432

user If `user=` is set, all connections to the destination database are initiated as the specified user, resulting in a single connection pool for the database.

If the `user=` parameter is not set, PgBouncer attempts to log in to the destination database with the user name passed by the client. In this situation, there will be one pool for each user who connects to the database.

password If no password is specified here, the password from the `auth_file` or `auth_query` will be used.

auth_user Override of the global `auth_user` setting, if specified.

client_encoding Ask for specific `client_encoding` from server.

datestyle Ask for specific `datestyle` from server.

timezone Ask for specific `timezone` from server.

Pool Configuration

You can use the following parameters for database-specific pool configuration.

pool_size Set the maximum size of pools for this database. If not set, the `default_pool_size` is used.

min_pool_size Set the minimum pool size for this database. If not set, the global `min_pool_size` is used.

It is only enforced if at least one of the following is true:

```
- This entry in the `[database]` section has a value set for the `user`.
- There i at least one client connected to the pool.
```

reserve_pool Set additional connections for this database. If not set, `reserve_pool_size` is used.

connect_query Query to be run after a connection is established, but before allowing the connection to be used by any clients. If the query raises errors, they are logged but ignored otherwise.

pool_mode Set the pool mode specific to this database. If not set, the default `pool_mode` is used.

max_db_connections Set a database-wide maximum number of PgBouncer connections for this database. The total number of connections for all pools for this database will not exceed this value.

[pgbouncer] Section

Generic Settings

logfile The location of the log file. For daemonization (`-d`), either this or `syslog` need to be set. The log file is kept open. After log rotation, run `kill -HUP pgbouncer` or run the `RELOAD` command in the PgBouncer Administration Console.

Note that setting `logfile` does not by itself turn off logging to `stderr` . Use the command-line option `-q` or `-d` for that.

```
Default: not set
```

pidfile The name of the pid file. Without a `pidfile` , you cannot run PgBouncer as a background (daemon) process.

```
Default: not set
```

listen_addr Specifies a list of comma-separated interface addresses where PgBouncer listens for TCP connections. You may also use `*` , which means to listen on all interfaces. If not set, only Unix socket connections are accepted.

```
Specify addresses numerically \(IPv4/IPv6\) or by name.

Default: not set
```

listen_port The port PgBouncer listens on. Applies to both TCP and Unix sockets.

```
Default: 6432
```

unix_socket_dir Specifies the location for the Unix sockets. Applies to both listening socket and server connections. If set to an empty string, Unix sockets are deactivated. A value that starts with @ specifies that a Unix socket in the abstract namespace should be created.

For online reboot (`-R`) to work, a Unix socket needs to be configured, and it needs to be in the file-system namespace.

```
Default: `/tmp`
```

unix_socket_mode Filesystem mode for the Unix socket. Ignored for sockets in the abstract namespace.

```
Default: 0777
```

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unix_socket_group Group name to use for Unix socket. Ignored for sockets in the abstract namespace.

```
Default: not set
```

user If set, specifies the Unix user to change to after startup. This works only if PgBouncer is started as root or if it is already running as the given user.

```
Default: not set
```

pool_mode Specifies when a server connection can be reused by other clients.

```
- `session`: Connection is returned to the pool when the client disconnects. Default.
- `transaction`: Connection is returned to the pool when the transaction finishes.
- `statement`: Connection is returned to the pool when the current query finishes. Transactions spanning multiple statements are disallowed in this mode.
```

max_client_conn Maximum number of client connections allowed. When increased, you should also increase the file descriptor limits. The actual number of file descriptors used is more than `max_client_conn`. The theoretical maximum used, when each user connects with its own username to the server is:

```
```
max_client_conn + (max pool_size * total databases * total users)
```
```

If a database user is specified in the connect string, all users connect using the same username. Then the theoretical maximum connections is:

```
```
max_client_conn + (max pool_size * total databases)
```
```

The theoretical maximum should be never reached, unless someone deliberately crafts a special load for it. Still, it means you should set the number of file descriptors to a safely high number. Search for `ulimit` in your operating system documentation.

Default: 100
```

default_pool_size The number of server connections to allow per user/database pair. This can be overridden in the per-database configuration.

```
Default: 20
```

min_pool_size Add more server connections to the pool when it is lower than this number. This improves behavior when the usual load drops and then returns suddenly after a period of total inactivity. The value is effectively capped at the pool size.

```
Default: 0 \(deactivated\)
```

reserve_pool_size The number of additional connections to allow for a pool (see `reserve_pool_timeout`). `0` deactivates.

```
Default: 0 \(deactivated\)
```

reserve_pool_timeout If a client has not been serviced in this many seconds, PgBouncer enables use of additional connections from the reserve pool. `0` deactivates.

```
Default: 5.0
```

max_db_connections Do not allow more than this many server connections per database (regardless of user). This considers the PgBouncer database that the client has connected to, not the PostgreSQL database of the outgoing connection.

This can also be set per database in the `[databases]` section.

Note that when you hit the limit, closing a client connection to one pool will not immediately allow a server connection to be established for another pool, because the server connection for the first pool is still open. Once the server connection closes (due to idle timeout), a new server connection will immediately be opened for the waiting pool.

Default: 0 (unlimited)

max_user_connections Do not allow more than this many server connections per user (regardless of database). This considers the PgBouncer user that is associated with a pool, which is either the user specified for the server connection or in absence of that the user the client has connected as.

This can also be set per user in the `[users]` section.

Note that when you hit the limit, closing a client connection to one pool will not immediately allow a server connection to be established for another pool, because the server connection for the first pool is still open. Once the server connection closes (due to idle timeout), a new server connection will immediately be opened for the waiting pool.

Default: 0 (unlimited)

server_round_robin By default, PgBouncer reuses server connections in LIFO (last-in, first-out) order, so that a few connections get the most load. This provides the best performance when a single server serves a database. But if there is TCP round-robin behind a database IP, then it is better if PgBouncer also uses connections in that manner to achieve uniform load.

```
Default: 0
```

track_extra_parameters By default, PgBouncer tracks the `client_encoding`, `datestyle`, `timezone`, `standard_conforming_strings`, and `application_name` parameters per client. To allow other parameters to be tracked, you may specify them under this parameter, so that PgBouncer knows that they should be maintained in the client variable cache and restored in the server whenever the client becomes active.

If you need to specify multiple values, use a comma-separated list.

Note that most parameters cannot be tracked this way. The only parameters that can be tracked are ones that WarehousePG reports to the client. WarehousePG has an official list of parameters that it reports to the client. WarehousePG extensions can change this list though, they can add parameters themselves that they also report, and they can start reporting already existing parameters that WarehousePG does not report.

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```

The WarehousePG protocol allows specifying parameters settings, both directly as a parameter in the startup packet, or inside the options startup packet. Parameters specified using both of these methods are supported by track_extra_parameters. However, it is not possible to include options itself in `track_extra_parameters`, only the parameters contained in `options`.

Default: IntervalStyle

ignore_startup_parameters By default, PgBouncer allows only parameters it can keep track of in startup packets: `client_encoding`, `datestyle`, `timezone`, and `standard_conforming_strings`. All others parameters raise an error. To allow other parameters, specify them here so that PgBouncer knows that they are handled by the admin and it can ignore them.

If you need to specify multiple values, use a comma-separated list.

The WarehousePG protocol allows specifying parameters settings, both directly as a parameter in the startup packet, or inside the `options` startup packet. Parameters specified using both of these methods are supported by `ignore_startup_parameters`. It is even possible to include `options` itself in `track_extra_parameters`, which results in any unknown parameters contained inside `options` to be ignored.

```
Default: empty
```

peer_id The peer id used to identify this PgBouncer process in a group of PgBouncer processes that are peered together. The `peer_id` value should be unique within a group of peered PgBouncer processes. When set to 0, PgBouncer peering is disabled. See the `[peers]` section for more information. The maximum value that can be used for the `peer_id` is 16383.

Default: 0

disable_pqexec Deactivates Simple Query protocol (PQexec). Unlike Extended Query protocol, Simple Query protocol allows multiple queries in one packet, which allows some classes of SQL-injection attacks. Deactivating it can improve security. This means that only clients that exclusively use Extended Query protocol will work.

```
Default: 0
```

application_name_add_host Add the client host address and port to the application name setting set on connection start. This helps in identifying the source of bad queries. This logic applies only on start of connection. If `application_name` is later changed with `SET`, PgBouncer does not change it again.

```
Default: 0
```

conffile Show location of the current configuration file. Changing this parameter will result in PgBouncer using another config file for next `RELOAD` / `SIGHUP`.

```
Default: file from command line
```

service_name Used during win32 service registration.

```
Default: pgbouncer
```

job_name Alias for `service_name`.

stats_period Sets how often the averages shown in various `SHOW` commands are updated and how often aggregated statistics are written to the log (but see `log_stats`). [seconds]

```
Default: 60
```

max_prepared_statements

When set to a non-zero value, PgBouncer tracks protocol-level named prepared statements related commands sent by the client in transaction and statement pooling mode. PgBouncer makes sure that any statement prepared by a client is available on the backing server connection, even when the statement was originally prepared on another server connection.

PgBouncer internally examines all the queries that are sent as a prepared statement by clients and gives each unique query string an internal name with the format `PGBOUNCER_{unique_id}`. Prepared statements are only prepared using this name on the corresponding WarehousePG cluster. PgBouncer keeps track of the name that the client gave to each prepared statement. It rewrites each command that uses a prepared statement to use the matching internal name (for example, `PGBOUNCER_123`) before forwarding that command to the server. More importantly, if the prepared statement that the client wants to use is not prepared on the server yet, it automatically prepares that statement before forwarding the command that the client sent.

Note that this tracking and rewriting of prepared statement commands does not work for SQL-level prepared statement commands such as `PREPARE`, `EXECUTE`, `DEALLOCATE`, `DEALLOCATE ALL`, and `DISCARD ALL`. Running `DEALLOCATE ALL` and `DISCARD ALL` is especially problematic, since those commands appear to run successfully, but they interfere with the state of the server connection significantly without PgBouncer noticing, which in turn will very likely break the execution of any further prepared statements on that server connection.

The actual value of this setting controls the number of prepared statements kept active on a single server connection. When the setting is set to 0, prepared statement support for transaction and statement pooling is disabled. To get the best performance, you should try to ensure that this setting is larger than the amount of commonly used prepared statements in your application. Keep in mind that the higher this value, the larger the memory footprint of each PgBouncer connection will have on your WarehousePG coordinator, because it will keep more queries prepared on those connections. It also increases the memory footprint of PgBouncer itself, because it now needs to keep track of query strings.

The impact on PgBouncer memory usage is not that big:

```
- Each unique query is stored once in a global query cache.
- Each client connection keeps a buffer that it uses to rewrite packets. This is at most four times the size of `pkt_buf`. This limit is often not reached though,
it only happens when the queries in your prepared statements are between two and four times the size of `pkt_buf`.
```

Consider the following example scenario:

```
- There are 1000 active clients.
- The clients prepare 200 unique queries.
- The average size of a query is 5 kB.
- `pkt_buf` is set to the default of 4096 (4kB).
```

In this scenario, PgBouncer needs at most the following amount of memory to handle these prepared statements:

```
```
200 x 5kB + 1000 x 4 x 4kB = ~17MB of memory.
```
```

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Tracking prepared statements does not only come with a memory cost, but also with increased CPU usage, because PgBouncer needs to inspect and rewrite the queries. Multiple PgBouncer instances can listen on the same port to use more than one core for processing, see the `so_reuseport` option for details.

There are also performance benefits to prepared statements. Just as when connecting to WarehousePG directly, by preparing a query that is executed many times, it reduces the total amount of parsing and planning that needs to be done. The way that PgBouncer tracks prepared statements is especially beneficial to performance when multiple clients prepare the same queries. Because client connections automatically reuse a prepared statement on a server connection even if it was prepared by another client. As an example, if you have a `pool_size` of 20 and you have 100 clients that all prepare the exact same query, then the query is prepared (and thus parsed) only 20 times on the WarehousePG coordinator.

The reuse of prepared statements has one downside. If the return or argument types of a prepared statement changes across executions, WarehousePG throws an error such as:

```
```
ERROR: cached plan must not change result type
```
```

You can avoid such errors by not having multiple clients that use the exact same query string in a prepared statement, but expecting different argument or result types. One of the most common ways of running into this issue is during a DDL migration where you add a new column or change a column type on an existing table. In those cases you can run `RECONNECT` on the PgBouncer admin console after doing the migration to force a re-prepare of the query and make the error goes away.

Default: 0

Authentication Settings

auth_file The name of the file containing the user names and passwords to load. The file format is the same as the WarehousePG pg_auth file. Refer to thePgBouncer Authentication File Format for more information.

```
Default: not set
```

auth_hba_file HBA configuration file to use when `auth_type` is `hba`. Refer to the Configuring HBA-based Authentication for PgBouncer and Configuring LDAP-based Authentication for PgBouncer for more information.

```
Default: not set
```

auth_type How to authenticate users.

```
- `pam`: Use PAM to authenticate users. `auth_file` is ignored. This method is not compatible with databases using the `auth_user` option. The service name
reported to PAM is `pgbouncer`. PAM is not supported in the HBA configuration file.
- `hba`:  The actual authentication type is loaded from the `auth_hba_file`. This setting allows different authentication methods for different access paths, for
example: connections over Unix socket use the `peer` auth method, connections over TCP must use TLS.
- `cert`:  Clients must connect with TLS using a valid client certificate. The client's username is taken from CommonName field in the certificate.
- `md5`: Use MD5-based password check. `auth_file` may contain both MD5-encrypted or plain-text passwords. If `md5` is configured and a user has a SCRAM secret,
then SCRAM authentication is used automatically instead. This is the default authentication method.
- `scram-sha-256`: Use password check with SCRAM-SHA-256. `auth_file` has to contain SCRAM secrets or plain-text passwords.
- `plain`:  Clear-text password is sent over wire. *Deprecated*.
- `trust`: No authentication is performed. The username must still exist in the `auth_file`.
- `any`: Like the `trust` method, but the username supplied is ignored. Requires that all databases are configured to log in with a specific user. Additionally,
the console database allows any user to log in as admin.
```

auth_key_file If you are connecting to LDAP with an encrypted password, `auth_key_file` identifies the file system location of the encryption key. Refer to About Specifying an Encrypted LDAP Password for more information.

```
Default: not set
```

auth_cipher If you are connecting to LDAP with an encrypted password, `auth_cipher` identifies the cipher algorithm for password authentication. PgBouncer accepts any cipher supported by OpenSSL on the system. When FIPS mode is enabled, specify only a cipher that is considered safe in FIPS mode. Refer to About Specifying an Encrypted LDAP Password for more information.

```
Default: `aes-256-cbc`
```

auth_query Query to load a user's password from the database.

Direct access to pg_shadow requires admin rights. It's preferable to use a non-superuser that calls a `SECURITY DEFINER` function instead.

Note that the query is run inside target database, so if a function is used it needs to be installed into each database.

```
Default: `SELECT usename, passwd FROM pg_shadow WHERE usename=$1`
```

auth_user If `auth_user` is set, any user who is not specified in `auth_file` is authenticated through the `auth_query` query from the `pg_shadow` database view. PgBouncer performs this query as the `auth_user` WarehousePG user. `auth_user`'s password must be set in the `auth_file`. (If the `auth_user` does not require a password then it does not need to be defined in `auth_file`.)

Direct access to `pg_shadow` requires WarehousePG administrative privileges. It is preferable to use a non-admin user that calls `SECURITY DEFINER` function instead.

Default: not set

auth_dbname Database name in the `[database]` section to be used for authentication purposes. This option can be either global or overridden in the connection string if this parameter is specified.

Log Settings

syslog Toggles syslog on and off.

```
Default: 0
```

syslog_ident Under what name to send logs to syslog.

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```
Default: `pgbouncer` (program name)
```

syslog_facility Under what facility to send logs to syslog. Some possibilities are: `auth`, `authpriv`, `daemon`, `user`, `local0-7`.

```
Default: `daemon`
```

log_connections Log successful logins.

```
Default: 1
```

log_disconnections Log disconnections, with reasons.

```
Default: 1
```

log_pooler_errors Log error messages that the pooler sends to clients.

```
Default: 1
```

log_stats Write aggregated statistics into the log, every `stats_period`. This can be deactivated if external monitoring tools are used to grab the same data from `SHOW` commands.

```
Default: 1
```

verbose Increase verbosity. Mirrors the `-v` switch on the command line. Using `-v -v` on the command line is the same as `verbose=2`.

```
Default: 0
```

Console Access Control

admin_users Comma-separated list of database users that are allowed to connect and run all commands on the PgBouncer Administration Console. Ignored when `auth_type=any`, in which case any username is allowed in as admin.

```
Default: empty
```

stats_users Comma-separated list of database users that are allowed to connect and run read-only queries on the console. This includes all `SHOW` commands except `SHOW FDS`.

```
Default: empty
```

Connection Sanity Checks, Timeouts

server_reset_query Query sent to server on connection release, before making it available to other clients. At that moment no transaction is in progress so it should not include `ABORT` or `ROLLBACK`.

```
The query should clean any changes made to a database session so that the next client gets a connection in a well-defined state. Default is `DISCARD ALL` which
cleans everything, but that leaves the next client no pre-cached state. It can be made lighter, e.g. `DEALLOCATE ALL` to just drop prepared statements, if the
application does not break when some state is kept around.

> **Note** WarehousePG does not support `DISCARD ALL`.

When transaction pooling is used, the `server_reset_query` is not used, as clients must not use any session-based features as each transaction ends up in a
different connection and thus gets a different session state.

Default: `DISCARD ALL;` \(Not supported by WarehousePG.\)
```

server_reset_query_always Whether `server_reset_query` should be run in all pooling modes. When this setting is off (default), the `server_reset_query` will be run only in pools that are in sessions-pooling mode. Connections in transaction-pooling mode should not have any need for reset query.

```
This setting is for working around broken setups that run applications that use session features over a transaction-pooled PgBouncer. It changes non-deterministic
breakage to deterministic breakage: Clients always lose their state after each transaction.

Default: 0
```

server_check_delay How long to keep released connections available for immediate re-use, without running sanity-check queries on it. If `0`, then the query is run always.

```
Default: 30.0
```

server_check_query A simple do-nothing query to test the server connection.

```
If an empty string, then sanity checking is deactivated.

Default: SELECT 1;
```

server_fast_close Disconnect a server in session pooling mode immediately or after the end of the current transaction if it is in “close_needed” mode (set by `RECONNECT`, `RELOAD` that changes connection settings, or DNS change), rather than waiting for the session end. In statement or transaction pooling mode, this has no effect since that is the default behavior there.

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```
If because of this setting a server connection is closed before the end of the client session, the client connection is also closed. This ensures that the client notices that the session has been interrupted.

This setting makes connection configuration changes take effect sooner if session pooling and long-running sessions are used. The downside is that client sessions are liable to be interrupted by a configuration change, so client applications will need logic to reconnect and reestablish session state. But note that no transactions will be lost, because running transactions are not interrupted, only idle sessions.

Default: 0
```

server_lifetime The pooler will close an unused server connections that has been connected longer than this number of seconds. Setting it to `0` means the connection is to be used only once, then closed. [seconds]

```
Default: 3600.0
```

server_idle_timeout If a server connection has been idle more than this many seconds it is dropped. If this parameter is set to `0`, timeout is deactivated. [seconds]

```
Default: 600.0
```

server_connect_timeout If connection and login will not finish in this amount of time, the connection will be closed. [seconds]

```
Default: 15.0
```

server_login_retry If a login fails due to failure from `connect()` or authentication, that pooler waits this much before retrying to connect. [seconds]

```
Default: 15.0
```

client_login_timeout If a client connects but does not manage to login in this amount of time, it is disconnected. This is needed to avoid dead connections stalling `SUSPEND` and thus online restart. [seconds]

```
Default: 60.0
```

autodb_idle_timeout If database pools created automatically (via `*`) have been unused this many seconds, they are freed. Their statistics are also forgotten. [seconds]

```
Default: 3600.0
```

dns_max_ttl How long to cache DNS lookups, in seconds. If a DNS lookup returns several answers, PgBouncer round-robins between them in the meantime. The actual DNS TTL is ignored. [seconds]

```
Default: 15.0
```

dns_nxdomain_ttl How long error and NXDOMAIN DNS lookups can be cached. [seconds]

```
Default: 15.0
```

dns_zone_check_period Period to check if zone serial numbers have changed.

```
PgBouncer can collect DNS zones from hostnames \(everything after first dot\) and then periodically check if the zone serial numbers change. If changes are detected, all hostnames in that zone are looked up again. If any host IP changes, its connections are invalidated.

Works only with UDNS and c-ares backend \(`--with-udns` or `--with-cares` to configure\).

Default: 0.0 \(deactivated\)
```

resolv_conf The location of a custom `resolv.conf` file. This is to allow specifying custom DNS servers and perhaps other name resolution options, independent of the global operating system configuration.

```
Requires evdns (>= 2.0.3) or c-ares (>= 1.15.0) backend.

The parsing of the file is done by the DNS backend library, not PgBouncer, so see the library's documentation for details on allowed syntax and directives.

Default: empty (use operating system defaults)
```

TLS settings

client_tls_sslmode TLS mode to use for connections from clients. TLS connections are deactivated by default. When enabled, `client_tls_key_file` and `client_tls_cert_file` must be also configured to set up the key and certificate PgBouncer uses to accept client connections.

```
-   `disable`: Plain TCP. If client requests TLS, it’s ignored. Default.
-   `allow`: If client requests TLS, it is used. If not, plain TCP is used. If client uses client-certificate, it is not validated.
-   `prefer`: Same as `allow`.
-   `require`: Client must use TLS. If not, client connection is rejected. If client presents a client-certificate, it is not validated.
-   `verify-ca`: Client must use TLS with valid client certificate.
-   `verify-full`: Same as `verify-ca`.
```

client_tls_key_file Private key for PgBouncer to accept client connections.

Default: not set

client_tls_cert_file Certificate for private key. CLients can validate it.

Default: unset

client_tls_ca_file Root certificate to validate client certificates.

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Default: unset

client_tls_protocols Which TLS protocol versions are allowed.

Valid values: are `tlsv1.0`, `tlsv1.1`, `tlsv1.2`, `tlsv1.3`.

Shortcuts: `all` (`tlsv1.0`, `tlsv1.1`, `tlsv1.2`, `tlsv1.3`), `secure` (`tlsv1.2`, `tlsv1.3`), `legacy` (`all`).

Default: `secure`

client_tls_ciphers Allowed TLS ciphers, in OpenSSL syntax. Shortcuts: `default`/`secure`, `compat`/`legacy`, `insecure`/`all`, `normal`, `fast`.

```
Only connections using TLS version 1.2 and lower are affected. There is currently no setting that controls the cipher choices used by TLS version 1.3 connections.

Default: `fast`
```

client_tls_ecdhcurve Elliptic Curve name to use for ECDH key exchanges.

Allowed values: `none` (DH is deactivated), `auto` (256-bit ECDH), curve name.

Default: `auto`

client_tls_dheparams DHE key exchange type.

Allowed values: `none` (DH is deactivated), `auto` (2048-bit DH), `legacy` (1024-bit DH).

Default: `auto`

server_tls_sslmode TLS mode to use for connections to WarehousePG and PostgreSQL servers. TLS connections are deactivated by default.

```
-   `disable`: Plain TCP. TLS is not requested from the server. Default.
-   `allow`: If server rejects plain, try TLS. \(*PgBouncer Documentation is speculative on this.*\)
-   `prefer`: TLS connection is always requested first. When connection is refused, plain TPC is used. Server certificate is not validated.
-   `require`: Connection must use TLS. If server rejects it, plain TCP is not attempted. Server certificate is not validated.
-   `verify-ca`: Connection must use TLS and server certificate must be valid according to `server_tls_ca_file`. The server hostname is not verfied against the
certificate.
-   `verify-full`: Connection must use TLS and the server certificate must be valid according to `server_tls_ca_file`. The server hostname must match the hostname
in the certificate.
```

server_tls_ca_file Root certificate file used to validate WarehousePG and PostgreSQL server certificates.

Default: unset

server_tls_key_file Private key for PgBouncer to authenticate against WarehousePG or PostgreSQL server.

Default: not set

server_tls_cert_file Certificate for private key. WarehousePG or PostgreSQL servers can validate it.

Default: not set

server_tls_protocols Which TLS protocol versions are allowed. Allowed values: `tlsv1.0`, `tlsv1.1`, `tlsv1.2`, `tlsv1.3`. Shortcuts: `all` (`tlsv1.0`, `tlsv1.1`, `tlsv1.2`, `tlsv1.3`); `secure` (`tlsv1.2`, `tlsv1.3`); `legacy` (`all`).

Default: `secure`

server_tls_ciphers Allowed TLS ciphers, in OpenSSL syntax. Shortcuts: `default`/`secure`, `compat`/`legacy`, `insecure`/`all`, `normal`, `fast`.

```
Only connections using TLS version 1.2 and lower are affected. There is currently no setting that controls the cipher choices used by TLS version 1.3 connections.

Default: `fast`
```

Dangerous Timeouts

Setting the following timeouts can cause unexpected errors.

query_timeout Queries running longer than this (seconds) are canceled. This parameter should be used only with a slightly smaller server-side `statement_timeout`, to apply only for network problems. [seconds]

```
Default: 0.0 \(deactivated\)
```

query_wait_timeout The maximum time, in seconds, queries are allowed to wait for execution. If the query is not assigned to a server during that time, the client is disconnected. This is used to prevent unresponsive servers from grabbing up connections. [seconds]

```
Default: 120
```

cancel_wait_timeout The maximum time, in seconds, cancellation requests are allowed to spend waiting for execution. If the cancel request is not assigned to a server during that time, the client is disconnected. A value of 0 disables the timeout. If it is disabled, cancel requests will be queued indefinitely.

This setting is used to prevent a client locking up when a cancel cannot be forwarded due to the server being down.

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Default: 10.0

client_idle_timeout Client connections idling longer than this many seconds are closed. This should be larger than the client-side connection lifetime settings, and only used for network problems. [seconds]

```
Default: 0.0 \(deactivated\)
```

idle_transaction_timeout If client has been in "idle in transaction" state longer than this (seconds), it is disconnected. [seconds]

```
Default: 0.0 \(deactivated\)
```

suspend_timeout How many seconds to wait for buffer flush during `SUSPEND` or reboot (`-R`). A connection is dropped if the flush does not succeed.

```
Default: 10
```

Low-level Network Settings

pkt_buf Internal buffer size for packets. Affects the size of TCP packets sent and general memory usage. Actual `libpq` packets can be larger than this so there is no need to set it large.

```
Default: 4096
```

max_packet_size Maximum size for packets that PgBouncer accepts. One packet is either one query or one result set row. A full result set can be larger.

```
Default: 2147483647
```

listen_backlog Backlog argument for the `listen(2)` system call. It determines how many new unanswered connection attempts are kept in queue. When the queue is full, further new connection attempts are dropped.

```
Default: 128
```

sbuf_loopcnt How many times to process data on one connection, before proceeding. Without this limit, one connection with a big result set can stall PgBouncer for a long time. One loop processes one `pkt_buf` amount of data. 0 means no limit.

```
Default: 5
```

so_reuseport Specifies whether to set the socket option `SO_REUSEPORT` on TCP listening sockets. On some operating systems, this allows running multiple PgBouncer instances on the same host listening on the same port and having the kernel distribute the connections automatically. This option is a way to get PgBouncer to use more CPU cores. (PgBouncer is single-threaded and uses one CPU core per instance.)

```
The behavior in detail depends on the operating system kernel. As of this writing, this setting has the desired effect on (sufficiently recent versions of) Linux, DragonFlyBSD, and FreeBSD. (On FreeBSD, it applies the socket option `SO_REUSEPORT_LB` instead.). Some other operating systems support the socket option but it won't have the desired effect: It will allow multiple processes to bind to the same port but only one of them will get the connections. See your operating system's `setsockopt()` documentation for details.

On systems that don’t support the socket option at all, turning this setting on will result in an error.

Each PgBouncer instance on the same host needs different settings for at least `unix_socket_dir` and `pidfile`, as well as `logfile` if that is used. Also note that if you make use of this option, you can no longer connect to a specific PgBouncer instance via TCP/IP, which might have implications for monitoring and metrics collection.

Default: 0
```

tcp_defer_accept For details on this and other TCP options, please see the tcp(7) man page.

```
Default: 45 on Linux, otherwise 0
```

tcp_socket_buffer Default: not set

tcp_keepalive Turns on basic keepalive with OS defaults.

```
On Linux, the system defaults are `tcp_keepidle=7200`, `tcp_keepintvl=75`, `tcp_keepcnt=9`. They are probably similar on other operating systems.

Default: 1
```

tcp_keepcnt Default: not set

tcp_keepidle Default: not set

tcp_keepintvl Default: not set

tcp_user_timeout Sets the `TCP_USER_TIMEOUT` socket option. This specifies the maximum amount of time in milliseconds that transmitted data may remain unacknowledged before the TCP connection is forcibly closed. If set to `0` , then the operating system's default is used.

Default: 0

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[users] Section

This section contains `key` = `value` pairs, where the `key` is a user name and the `value` is a `libpq` connect-string list of `key` = `value` pairs of configuration settings specific for this user. Only a few settings are available here.

pool_mode Set the pool mode for all connections from this user. If not set, the database or default `pool_mode` is used.

max_user_connection Configure a maximum for the user (i.e. all pools with the user will not have more than this many server connections).

For example:

```
[users]

user1 = pool_mode=transaction max_user_connections=10
```

[peers] Section

This section defines the peers that PgBouncer can forward cancellation requests to and where those cancellation requests will be routed.

PgBouncer processes can be peered together in a group by defining a `peer_id` value and a `[peers]` section in the configurations of all the PgBouncer processes. These PgBouncer processes can then forward cancellations requests to the process that it originated from. This is needed to make cancellations work when multiple PgBouncer processes, possibly on different servers, are behind the same TCP load balancer. Cancellation requests are sent over different TCP connections than the query they are cancelling, so a TCP load balancer might send the cancellation request connection to a different process than the one that it was meant for. By peering them these cancellation requests eventually end up at the right process.

The section contains key=value lines like

```
peer_id = connection string
```

Where the key will be taken as a `peer_id` and the value as a connection string, consisting of key=value pairs of connection parameters, described below (similar to `libpq`, but the actual `libpq` is not used and the set of available features is different). For example:

```
1 = host=host1.example.com
2 = host=/tmp/pgbouncer-2  port=5555
```

Note that for peering to work, the `peer_id` of each PgBouncer process in the group must be unique within the peered group. And the `[peers]` section should contain entries for each of those peer ids. It is allowed, but not necessary, for the i `[peers]` section to contain the `peer_id` of the PgBouncer that the configuration is for. Such an entry will be ignored, but it is allowed to make configuration management easy, because it allows using the exact same `[peers]` section for multiple configurations.

Note that cross-version peering is supported as long as all peers are on running 1.21.0 version or higher. In 1.21.0 some breaking changes were made in how we encode the cancellation tokens that made them incompatible with the ones created by earlier versions.

host Host name or IP address to connect to. Host names are resolved at connection time, the result is cached per the `dns_max_ttl` parameter. If DNS returns several results, they are used in a round-robin manner. But in general it is not recommended to use a hostname that resolves to multiple IPs, because then the cancel request might still be forwarded to the wrong node and it would need to be forwarded again (which is only allowed up to three times).

If the value begins with `/`, a Unix socket in the file-system namespace is used. If the value begins with `@`, a Unix socket in the abstract namespace is used.

Examples:

```
```
host=localhost
host=127.0.0.1
host=2001:0db8:85a3:0000:0000:8a2e:0370:7334
host=/var/run/pgbouncer-1
```
```

port The port to connect to. Default: 6432

pool_size Set the maximum number of cancel requests that can be in flight to the peer at the same time. It is quite normal for cancel requests to arrive in bursts, for example, when the backing Postgres server slows down. So it is important for `pool_size` to not be so low that it cannot handle these bursts.

If not set, the `default_pool_size` is used.

Example Configuration Files

Minimal Configuration

```
[databases]
postgres = host=127.0.0.1 dbname=postgres auth_user=gpadmin

[pgbouncer]
pool_mode = session
listen_port = 6543
listen_addr = 127.0.0.1
auth_type = md5
auth_file = users.txt
logfile = pgbouncer.log
pidfile = pgbouncer.pid
admin_users = someuser
stats_users = stat_collector
```

Use connection parameters passed by the client:

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```
[databases]
* =

[pgbouncer]
listen_port = 6543
listen_addr = 0.0.0.0
auth_type = trust
auth_file = bouncer/users.txt
logfile = pgbouncer.log
pidfile = pgbouncer.pid
ignore_startup_parameters=options
```

Database Defaults

```
[databases]

; foodb over unix socket
foodb =

; redirect bardb to bazdb on localhost
bardb = host=127.0.0.1 dbname=bazdb

; access to destination database will go with single user
forcedb = host=127.0.0.1 port=300 user=baz password=foo client_encoding=UNICODE datestyle=ISO
```

Example of a secure function for `auth_query`:

```
CREATE OR REPLACE FUNCTION pgbouncer.user_lookup(in i_username text, out uname text, out phash text)
RETURNS record AS $$
BEGIN
    SELECT usename, passwd FROM
pg_catalog.pg_shadow
    WHERE usename = i_username INTO uname,
phash;
    RETURN;
END;
$$ LANGUAGE plpgsql SECURITY
DEFINER;
REVOKE ALL ON FUNCTION pgbouncer.user_lookup(text) FROM public, pgbouncer;
GRANT EXECUTE ON FUNCTION pgbouncer.user_lookup(text) TO pgbouncer;
```

Example configuration for two peered PgBouncer processes to create a multi-core PgBouncer setup using `so_reuseport`. The configuration for the first process is:

```
[databases]
postgres = host=localhost dbname=postgres

[peers]
1 = host=/tmp/pgbouncer1
2 = host=/tmp/pgbouncer2

[pgbouncer]
listen_addr=127.0.0.1
auth_file=auth_file.conf
so_reuseport=1
unix_socket_dir=/tmp/pgbouncer1
peer_id=1
```

The configuration for the second process is:

```
[databases]
postgres = host=localhost dbname=postgres

[peers]
1 = host=/tmp/pgbouncer1
2 = host=/tmp/pgbouncer2

[pgbouncer]
listen_addr=127.0.0.1
auth_file=auth_file.conf
so_reuseport=1
; only unix_socket_dir and peer_id are different
unix_socket_dir=/tmp/pgbouncer2
peer_id=2
```

See Also

pgbouncer, pgbouncer-admin, PgBouncer Configuration Page

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7.7.3 Additional Supplied Utilities

Additional programs available in the WarehousePG installation.

The following PostgreSQL `contrib` server utility programs are installed:

- pg_xlogdump - Server utility program to display a human-readable rendering of the write-ahead log of a WarehousePG cluster.

Parent topic: WarehousePG Utility Guide

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7.8 System Catalogs

This reference describes the WarehousePG cluster catalog tables, views, and functions. System tables prefixed with `gp_` relate to the parallel features of WarehousePG. Tables prefixed with `pg_` are either standard PostgreSQL system catalog tables supported in WarehousePG, or are related to features WarehousePG that provides to enhance PostgreSQL for data warehousing workloads. Note that the global system catalog for WarehousePG resides on the coordinator instance.

> **Caution** Changes to WarehousePG cluster catalog tables or views are not supported. If a catalog table or view is changedby the customer, the WarehousePG cluster is not supported. The cluster must be reinitialized and restored by the customer.

- System Tables
- System Views
- System Catalogs Definitions
- System Catalog Functions

Parent topic: WarehousePG Reference Guide

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7.8.1 System Tables

- gp_configuration_history
- gp_distribution_policy
- gp_fastsequence
- gp_id
- gp_partition_template
- gp_segment_configuration
- gp_version_at_initdb
- gpexpand.status
- gpexpand.status_detail
- pg_aggregate
- pg_am
- pg_amop
- pg_amproc
- pg_appendonly
- pg_attrdef
- pg_attribute
- pg_attribute_encoding
- pg_auth_members
- pg_authid
- pg_cast
- pg_class
- pg_constraint
- pg_compression
- pg_conversion
- pg_database
- pg_db_role_setting
- pg_depend
- pg_description
- pg_enum
- pg_extension
- pg_foreign_data_wrapper
- pg_foreign_server
- pg_foreign_table
- pg_index
- pg_inherits
- pg_language
- pg_largeobject
- pg_namespace
- pg_opclass
- pg_operator
- pg_opfamily
- pg_partitioned_table
- pg_pltemplate
- pg_policy
- pg_proc
- pg_resgroup
- pg_resgroupcapability
- pg_resourcetype
- pg_resqueue
- pg_resqueuecapability
- pg_rewrite
- pg_sequence
- pg_shdepend
- pg_shdescription
- pg_stat_last_operation
- pg_stat_last_shoperation
- pg_statistic
- pg_statistic_ext
- pg_statistic_ext_data
- pg_tablespace
- pg_trigger
- pg_type
- pg_type_encoding
- pg_user_mapping

Parent topic: System Catalogs

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7.8.2 System Views

WarehousePG provides the following system views:

- gp_backend_memory_contexts
- gp_config
- gp_cursors
- gp_distributed_log
- gp_distributed_xacts
- gp_endpoints
- gp_file_settings
- gp_pgdatabase
- gp_replication_origin_status
- gp_replication_slots
- gp_resgroup_config
- gp_resgroup_iostats_per_host
- gp_resgroup_status
- gp_resgroup_status_per_host
- gp_resgroup_status_per_segment
- gp_resqueue_status
- gp_segment_endpoints
- gp_session_endpoints
- gp_settings
- gp_suboverflowed_backend
- gp_stat_activity
- gp_stat_all_indexes
- gp_stat_all_tables
- gp_stat_archiver
- gp_stat_bgwriter
- gp_stat_database
- gp_stat_database_conflicts
- gp_stat_gssapi
- gp_stat_operations
- gp_stat_progress_analyze
- gp_stat_progress_basebackup
- gp_stat_progress_cluster
- gp_stat_progress_copy
- gp_stat_progress_create_index
- gp_stat_progress_dtx_recovery
- gp_stat_progress_vacuum
- gp_stat_replication
- gp_stat_resqueues
- gp_stat_slru
- gp_stat_ssl
- gp_stat_subscription
- gp_stat_sys_indexes
- gp_stat_sys_tables
- gp_stat_user_functions
- gp_stat_user_indexes
- gp_stat_user_tables
- gp_stat_wal_receiver
- gp_stat_wal
- gp_stat_xact_all_tables
- gp_stat_xact_sys_tables
- gp_stat_xact_user_functions
- gp_stat_xact_user_tables
- gp_statio_all_indexes
- gp_statio_all_sequences
- gp_statio_all_tables
- gp_statio_sys_indexes
- gp_statio_sys_sequences
- gp_statio_sys_tables
- gp_statio_user_indexes
- gp_statio_user_sequences
- gp_statio_user_tables
- gp_stats
- gp_stats_ext
- gp_transaction_log
- gpexpand.expansion_progress
- pg_backend_memory_contexts
- pg_cursors
- pg_exttable
- pg_matviews
- pg_max_external_files
- pg_policies
- pg_resqueue_attributes
- pg_resqueue_status (Deprecated. Use gp_toolkit.gp_resqueue_status.)
- pg_stat_activity
- pg_stat_all_indexes
- pg_stat_all_tables
- pg_stat_operations
- pg_stat_replication
- pg_stat_resqueues
- pg_stat_slru
- pg_stat_wal
- pg_stats
- pg_stats_ext
- session_level_memory_consumption (See Monitoring a WarehousePG cluster.)

Summary Views

For more information on summary views, see Summary Views, below.

- gp_stat_all_indexes_summary
- gp_stat_all_tables_summary
- gp_stat_archiver_summary
- gp_stat_bgwriter_summary

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- gp_stat_database_summary
- gp_stat_progress_analyze_summary
- gp_stat_progress_basebackup_summary
- gp_stat_progress_cluster_summary
- gp_stat_progress_copy_summary
- gp_stat_progress_create_index_summary
- gp_stat_progress_dtx_recovery
- gp_stat_progress_vacuum_summary
- gp_stat_slru_summary
- gp_stat_sys_indexes_summary
- gp_stat_user_functions_summary
- gp_stat_user_indexes_summary
- gp_stat_wal_summary
- gp_stat_xact_all_tables_summary
- gp_stat_xact_sys_tables_summary
- gp_stat_xact_user_functions_summary
- gp_stat_xact_user_tables_summary
- gp_statio_all_indexes_summary
- gp_statio_all_sequences_summary
- gp_statio_all_tables_summary
- gp_statio_sys_indexes_summary
- gp_statio_sys_sequences_summary
- gp_statio_sys_tables_summary
- gp_statio_user_indexes_summary
- gp_statio_user_sequences_summary
- gp_statio_user_tables_summary

For more information about the standard system views supported in PostgreSQL and WarehousePG, see the following sections of the PostgreSQL documentation:

- System Views
- Statistics Collector Views
- The Information Schema

gp_backend_memory_contexts

The `gp_backend_memory_contexts` view is a cluster-wide view that displays the `pg_backend_memory_contexts` information from every primary segment.

column	type	references	description
`gp_segment_id`	integer		Unique identifier of a segment (or coordinator) instance.
`name`	text		The name of the memory context.
`ident`	text		Identification information of the memory context. This field is truncated at 1024 bytes.
`parent`	text		The name of the parent of this memory context.
`level`	int4		The distance from `TopMemoryContext` in context tree.
`total_bytes`	int8		The total number of bytes allocated for this memory context.
`total_nblocks`	int8		The total number of blocks allocated for this memory context.
`free_bytes`	int8		Free space in bytes.
`free_chunks`	int8		The total number of free chunks.
`used_bytes`	int8		Used space in bytes.

gp_config

The `gp_config` view is a cluster-wide view that displays the `pg_config` information from every primary segment.

column	type	references	description
`gp_segment_id`	integer		Unique identifier of a segment (or coordinator) instance.
`name`	text		The parameter name.
`setting`	text		The parameter value.

gp_cursors

The `gp_cursors` view is a cluster-wide view that displays the `pg_config` information from every primary segment.

name	type	references	description
`gp_segment_id`	integer		Unique identifier of a segment (or coordinator) instance.
`name`	text		The name of the cursor.
`statement`	text		The verbatim query string submitted to declare this cursor.
`is_holdable`	boolean		`true` if the cursor is holdable (that is, it can be accessed after the transaction that declared the cursor has committed); `false` otherwise. **Note** WarehousePG does not support holdable parallel retrieve cursors, this value is always `false` for such cursors.
`is_binary`	boolean		`true` if the cursor was declared `BINARY`; `false` otherwise.
`is_scrollable`	boolean		`true` if the cursor is scrollable (that is, it allows rows to be retrieved in a nonsequential manner); `false` otherwise. **Note** WarehousePG does not support scrollable cursors, this value is always `false`.
`creation_time`	timestamptz		The time at which the cursor was declared.

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name	type	references	description
`is_parallel`	boolean		`true` if the cursor was declared `PARALLEL RETRIEVE`; `false` otherwise.

gp_distributed_log

The `gp_distributed_log` view contains status information about distributed transactions and their associated local transactions. A distributed transaction is a transaction that involves modifying data on the segment instances. WarehousePG's distributed transaction manager ensures that the segments stay in synch. This view allows you to see the status of distributed transactions.

column	type	references	description
`segment_id`	smallint	gp_segment_configuration.content	The content id of the segment. The coordinator is always -1 (no content).
`dbid`	smallint	gp_segment_configuration.dbid	The unique id of the segment instance.
`distributed_xid`	xid		The global transaction id.
`distributed_id`	text		A system assigned ID for a distributed transaction.
`status`	text		The status of the distributed transaction (Committed or Aborted).
`local_transaction`	xid		The local transaction ID.

gp_distributed_xacts

The `gp_distributed_xacts` view contains information about WarehousePG distributed transactions. A distributed transaction is a transaction that involves modifying data on the segment instances. WarehousePG's distributed transaction manager ensures that the segments stay in synch. This view allows you to see the currently active sessions and their associated distributed transactions.

column	type	references	description
`distributed_xid`	xid		The transaction ID used by the distributed transaction across the WarehousePG cluster.
`distributed_id`	text		The distributed transaction identifier. It has 2 parts — a unique timestamp and the distributed transaction number.
`state`	text		The current state of this session with regards to distributed transactions.
`gp_session_id`	int		The ID number of the WarehousePG session associated with this transaction.
`xmin_distributed_snapshot`	xid		The minimum distributed transaction number found among all open transactions when this transaction was started. It is used for MVCC distributed snapshot purposes.

gp_endpoints

The `gp_endpoints` view lists the endpoints created for all active parallel retrieve cursors declared by the current session user in the current database. When the WarehousePG superuser accesses this view, it returns a list of all endpoints created for all parallel retrieve cursors declared by all users in the current database.

Endpoints exist only for the duration of the transaction that defines the parallel retrieve cursor, or until the cursor is closed.

name	type	references	description
gp_segment_id	integer		The QE's endpoint `gp_segment_id`.
auth_token	text		The authentication token for a retrieve session.
cursorname	text		The name of the parallel retrieve cursor.
sessionid	integer		The identifier of the session in which the parallel retrieve cursor was created.
hostname	varchar(64)		The name of the host from which to retrieve the data for the endpoint.
port	integer		The port number from which to retrieve the data for the endpoint.
username	text		The name of the session user (not the current user); *you must initiate the retrieve session as this user*.
state	text		The state of the endpoint; the valid states are: READY: The endpoint is ready to be retrieved. ATTACHED: The endpoint is attached to a retrieve connection. RETRIEVING: A retrieve session is retrieving data from the endpoint at this moment. FINISHED: The endpoint has been fully retrieved. RELEASED: Due to an error, the endpoint has been released and the connection closed.
endpointname	text		The endpoint identifier; you provide this identifier to the `RETRIEVE` command.

gp_file_settings

The `gp_file_settings` view is a cluster-wide view that displays the `pg_file_settings` information from every primary segment.

name	type	references	description
`gp_segment_id`	integer		Unique identifier of a segment (or coordinator) instance.
`sourcefile`	text		Full path name of the configuration file.
`sourceline`	integer		Line number within the configuration file where the entry appears.
`seqno`	integer		Order in which the entries are processed (1..n).

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name	type	references	description
name	text		Configuration parameter name.
setting	text		Value to be assigned to the parameter.
applied	boolean		True if the value can be applied successfully.
error	text		If not null, an error message indicating why this entry could not be applied.

gp_pgdatabase

The gp_pgdatabase view displays the status of WarehousePG segment instances and whether they are acting as the mirror or the primary. The WarehousePG fault detection and recovery utilities use this view internally to identify failed segments.

column	type	references	description
dbid	smallint	gp_segment_configuration.dbid	System-assigned ID. The unique identifier of a segment (or coordinator) instance.
isprimary	boolean	gp_segment_configuration.role	Whether or not this instance is active. Is it currently acting as the primary segment (as opposed to the mirror).
content	smallint	gp_segment_configuration.content	The ID for the portion of data on an instance. A primary segment instance and its mirror will have the same content ID. For a segment the value is from 0-*N-1*, where *N* is the number of segments in WarehousePG. For the coordinator, the value is -1.
valid	boolean	gp_segment_configuration.mode	Whether or not this instance is up and the mode is either *s* (synchronized) or *n* (not in sync).
definedprimary	boolean	gp_segment_ configuration.preferred_role	Whether or not this instance was defined as the primary (as opposed to the mirror) at the time the system was initialized.

gp_replication_origin_status

The gp_replication_origin_status view is a cluster-wide view that displays the pg_replication_origin_status information from every primary segment.

name	type	references	description
gp_segment_id	integer		Unique identifier of a segment (or coordinator) instance.
local_id	oid	pg_replication_origin.roident	Internal node identifier.
external_id	text	pg_replication_origin.roname	External node identifier.
remote_lsn	pg_lsn		The origin node's LSN up to which data has been replicated.
local_lsn	pg_lsn		This node's LSN at which remote_lsn has been replicated. Used to flush commit records before persisting data to disk when using asynchronous commits.

gp_replication_slots

The gp_replication_slots view is a cluster-wide view that displays the pg_replication_slots information from every primary segment.

name	type	references	description
gp_segment_id	integer		Unique identifier of a segment (or coordinator) instance.
slot_name	name		A unique, cluster-wide identifier for the replication slot.
plugin	name		The base name of the shared object containing the output plugin this logical slot is using, or null for physical slots.
slot_type	text		The slot type - physical or logical.
datoid	oid	pg_database.oid	The OID of the database this slot is associated with, or null. Only logical slots have an associated database.
database	text	pg_database.datname	The name of the database this slot is associated with, or null. Only logical slots have an associated database.
temporary	boolean		True if this is a temporary replication slot. Temporary slots are not saved to disk and are automatically dropped on error or when the session has finished.
active	boolean		True if this slot is currently actively being used.
active_pid	integer		The process ID of the session using this slot if the slot is currently actively being used. NULL if inactive.
xmin	xid		The oldest transaction that this slot needs the database to retain. VACUUM cannot remove tuples deleted by any later transaction.
catalog_xmin	xid		The oldest transaction affecting the system catalogs that this slot needs the database to retain. VACUUM cannot remove catalog tuples deleted by any later transaction.
restart_ls n	pg_lsn		The address (LSN) of oldest WAL which still might be required by the consumer of this slot and thus won't be automatically removed during checkpoints. NULL if the LSN of this slot has never been reserved.
confirmed_flush_ lsn	pg_lsn		The address (LSN) up to which the logical slot's consumer has confirmed receiving data. Data older than this is not available anymore. NULL for physical slots.

gp_resgroup_config

The gp_toolkit.gp_resgroup_config view allows administrators to see the current CPU, memory, and concurrency limits for a resource group.

> **Note** The gp_resgroup_config view is valid only when resource group-based resource management is active.

column	type	references	description
groupid	oid	pg_resgroup.oid	The ID of the resource group.
groupname	name	pg_resgroup.rsgname	The name of the resource group.

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column	type	references	description
concurrency	text	pg_resgroupcapability.value for pg_resgroupcapability.reslimittype = 1	The concurrency (CONCURRENCY) value specified for the resource group.
cpu_max_percent	text	pg_resgroupcapability.value for pg_resgroupcapability.reslimittype = 2	The CPU limit (CPU_MAX_PERCENT) value specified for the resource group, or -1.
cpu_weight	text	pg_resgroupcapability.value for pg_resgroupcapability.reslimittype = 3	The scheduling priority of the resource group (CPU_WEIGHT).
cpuset	text	pg_resgroupcapability.value for pg_resgroupcapability.reslimittype = 4	The CPU cores reserved for the resource group (CPUSET), or -1.
memory_quota	text	pg_resgroupcapability.value for pg_resgroupcapability.reslimittype = 5	The memory quota (MEMORY_QUOTA) value specified for the resource group.
min_cost	text	pg_resgroupcapability.value for pg_resgroupcapability.reslimittype = 6	The minimum cost of a query plan to be included in the resource group (MIN_COST).
io_limit	text	pg_resgroupcapability.value for pg_resgroupcapability.reslimittype = 7	The maximum read/write sequential disk I/O throughput, and the maximum read/write I/O operations per second for the queries assigned to a specific tablespace (shown as the tablespace oid) and resource group (IO_LIMIT).

gp_resgroup_iostats_per_host

The gp_toolkit.gp_resgroup_iostats_per_host view allows administrators to see current disk I/O usage for each resource group on a per-host basis.

Memory amounts are specified in MBs.

> **Note** The gp_resgroup_iostats_per_host view is valid only when resource group-based resource management is active.

column	type	references	description
rsgname	name	pg_resgroup.rsgname	The name of the resource group
hostname	text	gp_segment_configuration.hostname	The hostname of the segment host
tablespace	name	pg_tablespace.spcname	The name of the tablespace
rbps	bigint		The real-time read sequential disk I/O throughput by the resource group on a host, in Bytes/s
wbps	bigint		The real-time write sequential disk I/O throughput by the resource group on a host, in Bytes/s
riops	bigint		The real-time read I/O operations per second by the resource group on a host
wiops	bigint		The real-time write I/O operations per second by the resource group on a host

Sample output for the gp_resgroup_iostats_per_host view:

```
SELECT * from gp_toolkit.gp_resgroup_iostats_per_host;
 rsgname        | hostname | tablespace       | rbps | wbps | riops | wiops
----------------+----------+------------------+------------------+------------------+-------------+-------------
 rg_test_group1 | mtspc    | pg_default       | 21356347               | 29369067               | 162           | 36
 rg_test_group2 | mtspc    | pg_default       | 0                | 0                | 0           | 0
 rg_test_group3 | mtspc    | pg_default       | 0                | 0                | 0           | 0
 rg_test_group4 | mtspc    | *                | 0                | 0                | 0           | 0
 rg_test_group5 | mtspc    | rg_io_limit_ts_1 | 0                | 0                | 0           | 0
(5 rows)
```

gp_resgroup_iostats_per_host

The gp_toolkit.gp_resgroup_iostats_per_host view allows administrators to see current disk I/O usage for each resource group on a per-host basis.

Memory amounts are specified in MBs.

> **Note** The gp_resgroup_iostats_per_host view is valid only when resource group-based resource management is active.

column	type	references	description
rsgname	name	pg_resgroup.rsgname	The name of the resource group.
hostname	text	gp_segment_configuration.hostname	The hostname of the segment host.
tablespace			
rbps			

|`

| cpu_usage |float| |The real-time CPU core usage by the resource group on a host. The value is the sum of the percentages of the CPU cores that are used by the resource group on the host.| | memory_usage |float| |The real-time memory usage of the resource group on each WarehousePG segment's host, in MB.|

Sample output for the gp_resgroup_iostats_per_host view:

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```
select * from gp_toolkit.gp_resgroup_status_per_host;
 rsgname       | hostname | tablespace | rbps (MB_read/s)
---------------+----------+------------+--------------
 admin_group   | zero     | pg_default | 80
 default_group | zero     | pg_default | 500
 system_group  | zero     | pg_default | 300
 rg_new_group  | zero     |
(4 rows)
```

gp_resgroup_status

The `gp_resgroup_status` view allows administrators to see status and activity for a resource group. It shows how many queries are waiting to run and how many queries are currently active in the system for each resource group. The view also displays current memory and CPU usage for the resource group.

> **Note** Resource groups use the Linux control groups (cgroups) configured on the host systems. The cgroups are used to manage host system resources. When resource groups use cgroups that are as part of a nested set of cgroups, resource group limits are relative to the parent cgroup allotment. For information about nested cgroups and WarehousePG resource group limits, see Using Resource Groups.

This view is accessible to all users.

column	type	references	description
rsgname	name	pg_resgroup.rsgname	The name of the resource group.
groupid	oid	pg_resgroup.oid	The ID of the resource group.
num_running	integer		The number of transactions currently running in the resource group.
num_queueing	integer		The number of currently queued transactions for the resource group.
num_queued	integer		The total number of queued transactions for the resource group since the WarehousePG cluster was last started, excluding the num_queueing.
num_executed	integer		The total number of transactions run in the resource group since the WarehousePG cluster was last started, excluding the num_running.
total_queue_duration	interval		The total time any transaction was queued since the WarehousePG cluster was last started.

Sample output for the `gp_resgroup_status` view:

```
select * from gp_toolkit.gp_resgroup_status;
 rsgname       | groupid | num_running | num_queueing | num_queued | num_executed | total_queue_duration |
---------------+---------+-------------+--------------+------------+--------------+----------------------------------
 default_group | 6437    | 0           | 0            | 0          | 0            | @ 0                  |
 admin_group   | 6438    | 1           | 0            | 0          | 13           | @ 0                  |
 system_group  | 6441    | 0           | 0            | 0          | 0            | @ 0                  |
(3 rows)
```

gp_resgroup_status_per_host

The `gp_toolkit.gp_resgroup_status_per_host` view allows administrators to see current memory and CPU usage and allocation for each resource group on a per-host basis.

Memory amounts are specified in MBs.

> **Note** The `gp_resgroup_status_per_host` view is valid only when resource group-based resource management is active.

column	type	references	description
rsgname	name	pg_resgroup.rsgname	The name of the resource group.
groupid	oid	pg_resgroup.oid	The ID of the resource group.
`hostname`	text	gp_segment_configuration.hostname	The hostname of the segment host.
`cpu_usage`	float		The real-time CPU core usage by the resource group on a host. The value is the sum of the percentages of the CPU cores that are used by the resource group on the host.
`memory_usage`	float		The real-time memory usage of the resource group on each WarehousePG segment's host, in MB.

Sample output for the `gp_resgroup_status_per_host` view:

```
select * from gp_toolkit.gp_resgroup_status_per_host;
 rsgname       | groupid | hostname | cpu_usage | memory_usage
---------------+---------+----------+-----------+--------------
 admin_group   | 6438    | zero     | 0.07      | 91.92
 default_group | 6437    | zero     | 0.00      | 0.00
 system_group  | 6441    | zero     | 0.02      | 53.04
(3 rows)
```

gp_resgroup_status_per_segment

The `gp_toolkit.gp_resgroup_status_per_segment` view allows administrators to see current memory usage usage calculated by vmem tracker and grouped by segment.

Memory amounts are specified in MBs.

> **Note** The `gp_resgroup_status_per_segment` view is valid only when resource group-based resource management is active.

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column	type	references	description
groupid	oid	pg_resgroup.oid	The ID of the resource group.
groupname	name	pg_resgroup.rsgname	The name of the resource group.
segment_id	smallint	gp_segment_configuration.content	The content ID for a segment instance on the segment host.
vmem_usage	The real-time memory usage of the resource group on each segment, in MB.		

gp_resqueue_status

The gp_toolkit.gp_resqueue_status view allows administrators to see status and activity for a resource queue. It shows how many queries are waiting to run and how many queries are currently active in the system from a particular resource queue.

> **Note** The gp_resqueue_status view is valid only when resource queue-based resource management is active.

column	type	references	description
queueid	oid	gp_toolkit.gp_resqueue_ queueid	The ID of the resource queue.
rsqname	name	gp_toolkit.gp_resqueue_ rsqname	The name of the resource queue.
rsqcountlimit	real	gp_toolkit.gp_resqueue_ rsqcountlimit	The active query threshold of the resource queue. A value of -1 means no limit.
rsqcountvalue	real	gp_toolkit.gp_resqueue_ rsqcountvalue	The number of active query slots currently being used in the resource queue.
rsqcostlimit	real	gp_toolkit.gp_resqueue_ rsqcostlimit	The query cost threshold of the resource queue. A value of -1 means no limit.
rsqcostvalue	real	gp_toolkit.gp_resqueue_ rsqcostvalue	The total cost of all statements currently in the resource queue.
rsqmemorylimit	real	gp_toolkit.gp_resqueue_ rsqmemorylimit	The memory limit for the resource queue.
rsqmemoryvalue	real	gp_toolkit.gp_resqueue_ rsqmemoryvalue	The total memory used by all statements currently in the resource queue.
rsqwaiters	integer	gp_toolkit.gp_resqueue_ rsqwaiter	The number of statements currently waiting in the resource queue.
rsqholders	integer	gp_toolkit.gp_resqueue_ rsqholders	The number of statements currently running on the system from this resource queue.

gp_segment_endpoints

The gp_segment_endpoints view lists the endpoints created in the QE for all active parallel retrieve cursors declared by the current session user. When the WarehousePG superuser accesses this view, it returns a list of all endpoints on the QE created for all parallel retrieve cursors declared by all users.

Endpoints exist only for the duration of the transaction that defines the parallel retrieve cursor, or until the cursor is closed.

column	type	references	description
auth_token	text		The authentication token for the retrieve session.
databaseid	oid		The identifier of the database in which the parallel retrieve cursor was created.
senderpid	integer		The identifier of the process sending the query results.
receiverpid	integer		The process identifier of the retrieve session that is receiving the query results.
state	text		The state of the endpoint; the valid states are: READY: The endpoint is ready to be retrieved. ATTACHED: The endpoint is attached to a retrieve connection. RETRIEVING: A retrieve session is retrieving data from the endpoint at this moment. FINISHED: The endpoint has been fully retrieved. RELEASED: Due to an error, the endpoint has been released and the connection closed.
gp_segment_id	integer		The QE's endpoint gp_segment_id.
sessionid	integer		The identifier of the session in which the parallel retrieve cursor was created.
username	text		The name of the session user (not the current user); *you must initiate the retrieve session as this user*.
endpointname	text		The endpoint identifier; you provide this identifier to the RETRIEVE command.
cursorname	text		The name of the parallel retrieve cursor.

gp_session_endpoints

The gp_session_endpoints view lists the endpoints created for all active parallel retrieve cursors declared by the current session user in the current session.

Endpoints exist only for the duration of the transaction that defines the parallel retrieve cursor, or until the cursor is closed.

column	type	references	description
gp_segment_id	integer		The QE's endpoint gp_segment_id.
auth_token	text		The authentication token for a retrieve session.
cursorname	text		The name of the parallel retrieve cursor.
sessionid	integer		The identifier of the session in which the parallel retrieve cursor was created.
hostname	varchar(64)		The name of the host from which to retrieve the data for the endpoint.
port	integer		The port number from which to retrieve the data for the endpoint.

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column	type	references	description
username	text		The name of the session user (not the current user); *you must initiate the retrieve session as this user.*
state	text		The state of the endpoint; the valid states are: READY: The endpoint is ready to be retrieved. ATTACHED: The endpoint is attached to a retrieve connection. RETRIEVING: A retrieve session is retrieving data from the endpoint at this moment. FINISHED: The endpoint has been fully retrieved. RELEASED: Due to an error, the endpoint has been released and the connection closed.
endpointname	text		The endpoint identifier; you provide this identifier to the `RETRIEVE` command.

gp_settings

The `gp_settings` view is a cluster-wide view that displays the `pg_settings` information from every primary segment.

name	type	references	description
`gp_segment_id`	integer		Unique identifier of a segment (or coordinator) instance.
`name`	text		Runtime configuration parameter name.
`setting`	text		Current value of the parameter.
`unit`	text		Implicit unit of the parameter.
`category`	text		Logical group of the parameter.
`short_desc`	text		A brief description of the parameter.
`extra_desc`	text		Additional, more detailed, description of the parameter.
`context`	text		Context required to set the parameter's value.
`vartype`	text		Parameter type (bool, enum, integer, real, or string)v
`source`	text		Source of the current parameter value.v
`min_val`	text		Minimum allowed value of the parameter (null for non-numeric values).
`max_val`	text		Maximum allowed value of the parameter (null for non-numeric values).
`enumvals`	text[]		Permitted values of an enum parameter (null for non-enum values).
`boot_val`	text		Parameter value assumed at server startup if the parameter is not otherwise set.
`reset_val`	text		Value that RESET would reset the parameter to in the current session.
`sourcefile`	text		Configuration file the current value was set in (null for values set from sources other than configuration files, or when examined by a user who is neither a superuser or a member of `pg_read_all_settings`); helpful when using include directives in configuration files.
`sourceline`	integer		Line number within the configuration file the current value was set at (null for values set from sources other than configuration files, or when examined by a user who is neither a superuser or a member of pg_read_all_settings).
`pending_restart`	boolean		`true` if the value has been changed in the configuration file but needs a restart; otherwise `false`.

gp_suboverflowed_backend

The `gp_suboverflowed_backend` view allows administrators to identify sessions in which a backend has subtransaction overflows, which can cause query performance degradation in the system, including catalog queries.

column	type	description
`segid`	integer	The id of the segment containing the suboverflowed backend.
`pids`	integer[]	A list of the pids of all suboverflowed backends on this segment.

For more information on handling suboverflowed backends to prevent performance issues, seeChecking for and Terminating Overflowed Backends.

gp_transaction_log

The `gp_transaction_log` view contains status information about transactions local to a particular segment. This view allows you to see the status of local transactions.

column	type	references	description
`segment_id`	smallint	gp_segment_configuration.content	The content id of the segment. The coordinator is always -1 (no content).
`dbid`	smallint	gp_segment_configuration.dbid	The unique id of the segment instance.
`transaction`	xid		The local transaction ID.
`status`	text		The status of the local transaction (Committed or Aborted).

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gpexpand.expansion_progress

The `gpexpand.expansion_progress` view contains information about the status of a system expansion operation. The view provides calculations of the estimated rate of table redistribution and estimated time to completion.

Status for specific tables involved in the expansion is stored in gpexpand.status_detail.

column	type	references	description
`name`	text		Name for the data field provided. Includes: Bytes Left Bytes Done Estimated Expansion Rate Estimated Time to Completion Tables Expanded Tables Left
`value`	text		The value for the progress data. For example: `Estimated Expansion Rate - 9.75667095996092 MB/s`

gp_stat_activity

The `gp_stat_activity` view is a cluster-wide view that displays the `pg_stat_activity` information from every primary segment.

column	type	references	description
`gp_segment_id`	integer		Unique identifier of a segment (or coordinator) instance.
`datid`	oid	pg_database.oid	Database OID
`datname`	name		Database name
`pid`	integer		Process ID of this backend
`sess_id`	integer		Session ID
`usesysid`	oid	pg_authid.oid	OID of the user logged into this backend
`usename`	name		Name of the user logged into this backend
`application_name`	text		Name of the application that is connected to this backend
`client_addr`	inet		IP address of the client connected to this backend. If this field is null, it indicates either that the client is connected via a Unix socket on the server machine or that this is an internal process such as autovacuum.
`client_hostname`	text		Host name of the connected client, as reported by a reverse DNS lookup of `client_addr`. This field will only be non-null for IP connections, and only when log_hostname is enabled.
`client_port`	integer		TCP port number that the client is using for communication with this backend, or -1 if a Unix socket is used
`backend_start`	timestamptz		Time backend process was started
`xact_start`	timestamptz		Transaction start time
`query_start`	timestamptz		Time query began execution
`state_change`	timestampz		Time when the `state` was last changed
`wait_event_type`	text		Type of event for which the backend is waiting
`wait_event`	text		Wait event name if backend is currently waiting
`state`	text		Current overall state of this backend. Possible values are: - `active`: The backend is running a query. - `idle`: The backend is waiting for a new client command. - `idle in transaction`: The backend is in a transaction, but is not currently running a query. - `idle in transaction (aborted)`: This state is similar to idle in transaction, except one of the statements in the transaction caused an error. - `fastpath function call`: The backend is running a fast-path function. - `disabled`: This state is reported if `track_activities` is deactivated in this backend.
`query`	text		Text of this backend's most recent query. If `state` is active this field shows the currently running query. In all other states, it shows the last query that was run.
`rsgid`	oid	pg_resgroup.oid	Resource group OID or `0`. See Note.
`rsgname`	text	pg_resgroup.rsgname	Resource group name or `unknown`. See Note.

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gp_stat_all_indexes

The `gp_stat_all_indexes` view is a cluster-wide view that displays the `pg_stat_indexes` information from every primary segment.

column	type	references	description
`gp_segment_id`	integer		Unique identifier of a segment (or coordinator) instance.
`relid`	oid		ID of the table for this index.
`indexrelid`	oid		OID of this index.
`schemaname`	name		Name of the schema this index is in.
`relname`	name		Name of the table for this index.
`indexrelname`	name		Name for this index.
`idx_scan`	bigint		Number of index scans initiated on this index.
`idx_tup_read`	bigint		Number of index entries returned by scans on this index.
`idx_tup_fetch`	bigint		Number of live table rows fetched by simple index scans using this index

This system view is summarized in the `gp_stat_all_indexes_summary` system view.

gp_stat_all_tables

The `gp_stat_all_tables` view is a cluster-wide view that displays the `pg_stat_tables` information from every primary segment.

column	type	references	description
`gp_segment_id`	integer		Unique identifier of a segment (or coordinator) instance.
`relid`	oid		OID of a table.
`schemaname`	name		Name of the schema this table is on.
`relname`	name		Name of this table.
`seq_scan`	bigint		Number of sequential scans initiated on this table.
`seq_tup_read`	bigint		Number of live rows fetched by sequential scans.
`idx_scan`	bigint		Number of index scans initiated on this table.
`idx_tup_fetch`	bigint		Number of live rows fetched by index scans.
`n_tup_ins`	bigint		Number of rows inserted.
`n_tup_upd`	bigint		Number of rows updated (includes HOT updated rows).
`n_tup_del`	bigint		Number of rows deleted.
`n_tup_hot_upd`	bigint		Number of rows HOT updated (that is, with no separate index update required).
`n_live_tup`	bigint		Estimated number of live rows.
`n_dead_tup`	bigint		Estimated number of dead rows.
`n_mod_since_analyze`	bigint		Estimated number of rows modified since this table was last analyzed.
`n_ins_since_vacuum`	bigint		Estimated number of rows inserted since this table was last vacuumed.
`last_vacuum`	timestamp with time zone		Last time at which this table was manually vacuumed (not counting `VACUUM FULL`).
`last_autovacuum`	timestamp with time zone		Last time at which this table was vacuumed by the autovacuum daemon.
`last_analyze`	timestamp with time zone		Last time at which this table was manually analyzed.
`last_autoanalyze`	timestamp with time zone		Last time at which this table was analyzed by the autovacuum daemon.
`vacuum_count`	bigint		Number of times this table has been manually vacuumed (not counting `VACUUM FULL`).
`autovacuum_count`	bigint		Number of times this table has been vacuumed by the autovacuum daemon.
`analyze_count`	bigint		Number of times this table has been manually analyzed.
`autoanalyze_count`	bigint		Number of times this table has been analyzed by the autovacuum daemon.

This system view is summarized in the `gp_stat_all_tables_summary` system view.

gp_stat_archiver

column	type	references	description
`gp_segment_id`	integer		Unique identifier of a segment (or coordinator) instance.
`archived_count`	bigint		Number of WAL files that have been successfully archived.
`last_archived_wal`	text		Name of the WAL file most recently successfully archived.
`last_archived_time`	timestamp with time zone		Time of the most recent successful archive operation.
`failed_count`	bigint		Number of failed attempts for archiving WAL files.
`last_failed_wal`	timestamp with time zone		Name of the WAL file of the most recent failed archival operation.
`last_failed_time`	bigint		Time of the most recent failed archival operation.
`stats_reset`	timestamp with time zone		Time at which these statistics were last reset.

This system view is summarized in the `gp_stat_archiver_summary` system view.

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gp_stat_bgwriter

column	type	references	description
gp_segment_id	integer		Unique identifier of a segment (or coordinator) instance.
checkpoints_timed	bigint		Number of scheduled checkpoints that have been performed.
checkpoints_req	bigint		Number of requested checkpoints that have been performed.
checkpoint_write_time	double precision		Total amount of time that has been spent in the portion of checkpoint processing where files are written to disk, in milliseconds.
checkpoint_sync_time	double precision		Total amount of time that has been spent in the portion of checkpoint processing where files are synchronized to disk, in milliseconds.
buffers_checkpoint	bigint		Number of buffers written during checkpoints.
buffers_clean	bigint		Number of buffers written by the background writer.
maxwritten_clean bigint		Number of times the background writer stopped a cleaning scan because it had written too many buffers.	
buffers_backend bigint		Number of buffers written directly by a backend.	
buffers_backend_fsync bigint		Number of times the background writer stopped a cleaning scan because it had written too many buffers.	
buffers_alloc	bigint		Number of buffers allocated.
stats_reset	timestamp with time zone		Time at which these statistics were last reset.

This system view is summarized in the gp_stat_bgwriter_summary system view.

gp_stat_database

column	type	references	description
gp_segment_id	integer		Unique identifier of a segment (or coordinator) instance.
datid	oid		OID of this database, or 0 for objects belonging to a shared relation.
datname	name		Name of this database, or NULL for shared objects.
numbackends	integer		Number of backends currently connected to this database, or NULL for shared objects. This is the only column in this view that returns a value reflecting current state; all other columns return the accumulated values since the last reset.
xact_commit	bigint		Number of transactions in this database that have been committed.
xact_rollback	bigint		Number of transactions in this database that have been rolled back.
blks_read	bigint		Number of disk blocks read in this database.
blks_hit	bigint		Number of times disk blocks were found already in the buffer cache, so that a read was not necessary (this only includes hits in the PostgreSQL buffer cache, not the operating system's file system cache).
tup_returned	bigint		Number of live rows fetched by sequential scans and index entries returned by index scans in this database.
tup_fetched	bigint		Number of live rows fetched by index scans in this database.
tup_inserted	bigint		Number of rows inserted by queries in this database.
tup_updated	bigint		Number of rows updated by queries in this database.
tup_deleted bigint	bigint		Number of rows deleted by queries in this database.
conflicts	bigint		Number of queries canceled due to conflicts with recovery in this database.
temp_files	bigint		Number of temporary files created by queries in this database. All temporary files are counted, regardless of why the temporary file was created (for example, sorting or hashing), and regardless of the log_temp_files setting.
temp_bytes	bigint		Total amount of data written to temporary files by queries in this database. All temporary files are counted, regardless of why the temporary file was created, and regardless of the log_temp_files setting.
deadlocks	bigint		Number of deadlocks detected in this database.
checksum_failures	bigint		Number of data page checksum failures detected in this database (or on a shared object), or NULL if data checksums are not enabled.
checksum_last_failure	timestamp with time zone		Time at which the last data page checksum failure was detected in this database (or on a shared object), or NULL if data checksums are not enabled.
blk_read_time	double precision		Time spent reading data file blocks by backends in this database, in milliseconds (if track_io_timing is enabled, otherwise zero).
session_time	double precision		Time spent by database sessions in this database, in milliseconds (note that statistics are only updated when the state of a session changes, so if sessions have been idle for a long time, this idle time won't be included).
active_time	double precision		Time spent executing SQL statements in this database, in milliseconds (this corresponds to the states active and fastpath function call in pg_stat_activity).
idle_in_transaction_time	double precision		Time spent idling while in a transaction in this database, in milliseconds (this corresponds to the states idle in transaction and idle in transaction (aborted) in gp_stat_activity)
sessions	bigint		Total number of sessions established to this database.
sessions_abandoned	bigint		Number of database sessions to this database that were terminated because connection to the client was lost.
sessions_fatal	bigint		Number of database sessions to this database that were terminated by fatal errors.
sessions_killed	bigint		Number of database sessions to this database that were terminated by operator intervention.
stats_reset	timestamp with time zone		Time at which these statistics were last reset.

This system view is summarized in the gp_stat_database_summary system view.

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gp_stat_database_conflicts

column	type	references	description
gp_segment_id	integer		Unique identifier of a segment (or coordinator) instance.
datid	oid		OID of a database.
datname	name		Name of this database.
confl_tablespace	bigint		Number of queries in this database that have been canceled due to dropped tablespaces.
confl_lock	bigint		Number of queries in this database that have been canceled due to lock timeouts.
confl_snapshot	bigint		Number of queries in this database that have been canceled due to old snapshots.
client_port	integer		Client port number.
confl_bufferpin	bigint		Number of queries in this database that have been canceled due to pinned buffers.
confl_deadlock	bigint		Number of queries in this database that have been canceled due to deadlocks.

gp_stat_gssapi

column	type	references	description
gp_segment_id	integer		Unique identifier of a segment (or coordinator) instance.
pid	integer		Process ID of a backend.
gss_authenticated boolean	boolean		True if GSSAPI authentication was used for this connection.
principal	text		Principal used to authenticate this connection, or NULL if GSSAPI was not used to authenticate this connection. This field is truncated if the principal is longer than NAMEDATALEN (64 characters in a standard build).
encrypted	boolean		True if GSSAPI encryption is in use on this connection.

gp_stat_operations

The view gp_stat_operations shows details about the last operation performed on a database object (such as a table, index, view or database) or a global object (such as a role).

column	type	references	description
gp_segment_id	integer		Unique identifier of a segment (or coordinator) instance.
classname	text		The name of the system table in the pg_catalog schema where the record about this object is stored (pg_class =relations, pg_database =databases, pg_namespace =schemas, pg_authid =roles)
objname	name		The name of the object.
objid	oid		The OID of the object.
schemaname	name		The name of the schema where the object resides.
usestatus	text		The status of the role who performed the last operation on the object (CURRENT =a currently active role in the system, DROPPED =a role that no longer exists in the system, CHANGED =a role name that exists in the system, but has changed since the last operation was performed).
usename	name		The name of the role that performed the operation on this object.
actionname	name		The action that was taken on the object.
subtype	text		The type of object operated on or the subclass of operation performed.
statime	timestamptz		The timestamp of the operation. This is the same timestamp that is written to the WarehousePG server log files in case you need to look up more detailed information about the operation in the logs.

gp_stat_progress_analyze

The gp_stat_progress_analyze view is a cluster-wide view that displays the pg_stat_progress_analyze information from every primary segment for all currently-running ANALYZE operations.

The gp_stat_progress_analyze_summary view aggregates across the WarehousePG cluster the metrics reported by gp_stat_progress_analyze.

Column	Type	Description
gp_segment_id	integer	Unique identifier of a segment (or coordinator) instance. (This column is not present in the gp_stat_progress_analyze_summary view.)
pid	integer	The process identifier of the backend, or the coordinator process identifier if the gp_stat_progress_analyze_summary view.
datid	oid	The object identifier of the database to which this backend is connected.
datname	name	Name of the database to which this backend is connected.
relid	oid	The object identifier of the table being analyzed.
phase	text	Current processing phase. Refer to ANALYZE Progress Reporting for detailed information about the phases.
sample_blks_total	bigint	Total number of heap blocks that will be sampled.
sample_blks_scanned	bigint	Number of heap blocks scanned.
ext_stats_total	bigint	Number of extended statistics.
ext_stats_computed	bigint	Number of extended statistics computed. This counter only advances when the phase is computing extended statistics.
child_tables_total	bigint	Number of child tables.
child_tables_done	bigint	Number of child tables scanned. This counter only advances when the phase is acquiring inherited sample rows.

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Column	Type	Description
current_child_table_relid	oid	The object identifier of the child table currently being scanned. This field is only valid when the phase is acquiring inherited sample rows. (This column is not present in the for gp_stat_progress_analyze_summary view.)

gp_stat_progress_basebackup

The gp_stat_progress_basebackup view is a cluster-wide view that displays the pg_stat_progress_basebackup information from every primary segment for all currently-running base backup operations (gprecoverseg).

The gp_stat_progress_basebackup_summary view aggregates across the WarehousePG cluster the metrics reported by gp_stat_progress_basebackup.

Column	Type	Description
gp_segment_id	integer	Unique identifier of a segment (or coordinator) instance. (This column is not present in the gp_stat_progress_basebackup_summary view.)
pid	integer	The process identifier of a WAL sender process, or the coordinator process identifier if the gp_stat_progress_basebackup_summary view.
phase	text	Current processing phase. Refer to Base Backup Progress Reporting for detailed information about the phases.
backup_total	bigint	Total amount of data that will be streamed. This is estimated and reported as of the beginning of streaming database files phase. Note that this is only an approximation since the database may change during streaming database files phase and WAL log may be included in the backup later. This is always the same value as backup_streamed once the amount of data streamed exceeds the estimated total size. NULL if the estimation is disabled in pg_basebackup.
backup_streamed	bigint	Amount of data streamed. This counter only advances when the phase is streaming database files or transferring wal files.
tablespaces_total	bigint	Total number of tablespaces that will be streamed.
tablespaces_streamed	bigint	Number of tablespaces streamed. This counter only advances when the phase is streaming database files.

gp_stat_progress_cluster

The gp_stat_progress_cluster view is a cluster-wide view that displays the pg_stat_progress_cluster information from every primary segment for all currently-running CLUSTER and VACUUM FULL (on a heap table) operations.

The gp_stat_progress_cluster_summary view aggregates across the WarehousePG cluster the metrics reported by gp_stat_progress_cluster.

Column	Type	Description
gp_segment_id	integer	Unique identifier of a segment (or coordinator) instance. (This column is not present in the gp_stat_progress_cluster_summary view.)
pid	integer	Process identifier of the backend, or the coordinator process identifier if the gp_stat_progress_cluster_summary view.
datid	oid	The object identifier of the database to which this backend is connected.
datname	name	Name of the database to which this backend is connected.
relid	oid	The object identifier of the table being clustered.
command	text	The name of the command that is running. Either CLUSTER or VACUUM FULL.
phase	text	Current processing phase. Refer to CLUSTER and VACUUM FULL Progress Reporting for detailed information about the phases.
cluster_index_relid	oid	If the table is being scanned using an index, this is the object identifier of the index being used; otherwise, it is zero. This field is not applicable to AO/CO tables.
heap_tuples_scanned	bigint	For heap tables, heap_tuples_scanned records the number of tuples scanned, including both live and dead tuples. For AO tables, heap_tuples_scanned records the number of live tuples scanned, excluding the dead tuples. This counter only advances when the phase is seq scanning append-optimized, seq scanning heap, index scanning heap, or writing new heap. For AO/CO tables, WarehousePG converts byte size into equivalent heap blocks in size.
heap_tuples_written	bigint	Number of tuples written. This counter only advances when the phase is seq scanning heap, index scanning heap, writing new append-optimized, or writing new heap.
heap_blks_total	bigint	Total number of heap blocks in the table. This number is reported as of the beginning of seq scanning heap. For AO/CO tables, WarehousePG converts byte size into equivalent heap blocks in size.
heap_blks_scanned	bigint	Number of heap blocks scanned. This counter only advances when the phase is seq scanning heap. For AO/CO tables, WarehousePG converts byte size into equivalent heap blocks in size.
index_rebuild_count	bigint	Number of indexes rebuilt. This counter only advances when the phase is rebuilding index, and is not applicable to AO/CO tables.

gp_stat_progress_copy

The gp_stat_progress_copy view is a cluster-wide view that displays the pg_stat_progress_copy information from every primary segment for all currently-running COPY operations.

The gp_stat_progress_copy_summary view aggregates across the WarehousePG cluster the metrics reported by gp_stat_progress_copy.

Column	Type	Description
gp_segment_id	integer	Unique identifier of a segment (or coordinator) instance. (This column is not present in the gp_stat_progress_copy_summary view.)
pid	integer	Process identifier of the backend, or the coordinator process identifier if the gp_stat_progress_copy_summary view.

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Column	Type	Description
datid	oid	The object identifier of the database to which this backend is connected.
datname	name	Name of the database to which this backend is connected.
relid	oid	The object identifier of the table on which the COPY command is executed. It is set to 0 if copying from a SELECT query.
command	text	The command that is running: COPY FROM, COPY TO, COPY FROM ON SEGMENT, or COPY TO ON SEGMENT.
type	text	The io type that the data is read from or written to: FILE, PROGRAM, PIPE (for COPY FROM STDIN and COPY TO STDOUT), or CALLBACK (used for example during the initial table synchronization in logical replication).
bytes_processed	bigint	Number of bytes already processed by COPY command.
bytes_total	bigint	Size of source file for COPY FROM command in bytes. It is set to 0 if not available.
tuples_processed	bigint	Number of tuples already processed by COPY command.
tuples_excluded	bigint	Number of tuples not processed because they were excluded by the WHERE clause of the COPY command.

gp_stat_progress_create_index

The gp_stat_progress_create_index view is a cluster-wide view that displays the pg_stat_progress_create_index information from every primary segment for all currently-running CREATE INDEX and REINDEX operations.

The gp_stat_progress_create_index_summary view aggregates across the WarehousePG cluster the metrics reported by gp_stat_progress_create_index.

Column	Type	Description
gp_segment_id	integer	Unique identifier of a segment (or coordinator) instance. (This column is not present in the gp_stat_progress_create_index_summary view.)
pid	integer	Process identifier of the backend, or the coordinator process identifier if the gp_stat_progress_create_index_summary view.
datid	oid	The object identifer of the database to which this backend is connected.
datname	name	Name of the database to which this backend is connected.
relid	oid	The object identifer of the table on which the index is being created.
index_relid	oid	The object identifer of the index being created or reindexed. Because WarehousePG does not support concurrent (re)indexing, this value is always 0.
command	text	The name of the command that is running: CREATE INDEX or REINDEX.
phase	text	Current processing phase of index creation. Refer to CREATE INDEX Progress Reporting for detailed information about the phases.
lockers_total	bigint	Total number of lockers to wait for, when applicable.
lockers_done	bigint	Number of lockers already waited for.
current_locker_pid	bigint	The process identifier of the locker currently being waited for.
blocks_total	bigint	Total number of blocks to be processed in the current phase.
blocks_done	bigint	Number of blocks already processed in the current phase.
tuples_total	bigint	Total number of tuples to be processed in the current phase.
tuples_done	bigint	Number of tuples already processed in the current phase.
partitions_total	bigint	When creating an index on a partitioned table, this column is set to the total number of partitions on which the index is to be created. This field is 0 during a REINDEX.
partitions_done	bigint	When creating an index on a partitioned table, this column is set to the number of partitions on which the index has been completed. This field is 0 during a REINDEX.

gp_stat_progress_dtx_recovery

The gp_stat_progress_dtx_recovery view is a cluster-wide view that displays the progress of the Distributed Transaction (DTX) Recovery process, which runs in the backgroup during Postgres startup.

This view may be useful if a coordinator restart remains in a recovery state for a long time. WarehousePG will not accept connections until all "in-doubt" transactions are resolved. In-doubt transactions are transactions that have been prepared but not committed yet. If there were many transactions running before the coordinator restarted, the recovery of the database may take longer than expected, and you may use this view to monitor the current phase of the recovery. Note that in this scenario, as WarehousePG is still starting up, you will need to access the database in utility mode to check this view.

Column	Type	Description
phase	text	Status of the recovery. The possible values are: 'initializing', 'recovering commited distributed transactions', 'gathering in-doubt transactions', 'aborting in-doubt transactions', 'gathering in-doubt orphaned transactions', and 'managing in-doubt orphaned transactions'.
recover_commited_dtx_total	integer	Total number of committed transactions found to recover.
recover_commited_dtx_completed	integer	Number of committed transactions that have been recovered.
in_doubt_tx_total`	integer	Total number of in-doubt transaction found, used in startup and non-startup phases.
in_doubt_tx_in_progress	integer	Number of in-progress, in-doubt transactions.
in_doubt_tx_aborted	integer	Number of aborted in-doubt transactions.

gp_stat_progress_vacuum

The gp_stat_progress_vacuum view is a cluster-wide view that displays the pg_stat_progress_vacuum information from every primary segment for all currently-running VACUUM and vacuumdb operations.

The gp_stat_progress_vacuum_summary view aggregates across the WarehousePG cluster the metrics reported by gp_stat_progress_vacuum.

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Column	Type	Description
`gp_segment_id`	integer	Unique identifier of a segment (or coordinator) instance. (This column is not present in the `gp_stat_progress_vacuum_summary` view.)
`pid`	integer	Process identifier of the backend, or the coordinator process identifier if the `gp_stat_progress_vacuum_summary` view.
`datid`	oid	The object identifier of the database to which this backend is connected.
`datname`	name	Name of the database to which this backend is connected.
`relid`	oid	The object identifier of the table being vacuumed.
`phase`	text	Current processing phase of vacuum. Refer to VACUUM Progress Reporting for detailed information about the phases.
`heap_blks_total`	bigint	*Heap tables*: Total number of heap blocks in the table. This number is reported as of the beginning of the scan; blocks added later will not be (and need not be) visited by this `VACUUM`. *AO/CO tables*[1]: Collected at the beginning of the `append-optimized pre-cleanup` phase by adding up the on-disk file sizes of all segment files of the relation, and converting the size into the number of heap-equivalent blocks. The value should not change while `VACUUM` progresses.
`heap_blks_scanned`	bigint	*Heap tables*: Number of heap blocks scanned. Because the visibility map is used to optimize scans, some blocks will be skipped without inspection; skipped blocks are included in this total, so that this number will eventually become equal to `heap_blks_total` when the vacuum is complete. This counter only advances when the phase is `scanning heap`. *AO/CO tables*:[1] The counter only advances when the phase is `append-optimized compact`. For `ao_row` tables, updated every time WarehousePG finishes scanning a segment file. For `ao_column` tables, updated every time WarehousePG moves a tuple. `heap_blks_scanned` can be less than or equal to `heap_blks_total` at the end of the `VACUUM` operation because WarehousePG does not need to scan blocks after the logical EOF of a segment file.
`heap_blks_vacuumed`	bigint	*Heap tables*: Number of heap blocks vacuumed. Unless the table has no indexes, this counter only advances when the phase is `vacuuming heap`. Blocks that contain no dead tuples are skipped, so the counter may sometimes skip forward in large increments. *AO/CO tables*[1]: The counter advances when WarehousePG truncates a segment file, which may happen during both `append-optimized pre-cleanup` and `append-optimized post-cleanup` phases. Because WarehousePG truncates physical blocks after the logical EOF in a segment file, `heap_blks_vacuumed` may be either smaller or larger than `heap_blks_scanned`.
`index_vacuum_count`	bigint	*Heap tables*: Number of completed index vacuum cycles. *AO/CO tables*: Collected when WarehousePG recycles a dead segment file, which may happen both, any, or neither, during `append-optimized pre-cleanup` phase and `append-optimized post-cleanup phase`.
`max_dead_tuples`	bigint	*Heap tables*: Number of dead tuples that we can store before needing to perform an index vacuum cycle, based on maintenance_work_mem. *AO/CO tables*: Collected at the beginning of the `append-optimized pre-cleanup` phase, this is the total number of tuples before the logical EOF of all segment files. The value should not change while `VACUUM` progresses.
`num_dead_tuples`	bigint	*Heap tables*: Number of dead tuples collected since the last index vacuum cycle. *AO/CO tables*: Collected during `append-optimized compact` phase. For `ao_row` tables, updated every time WarehousePG discares a dead tuple. For `ao_column` tables, updated every time WarehousePG moves a live tuple, and also when the number of dead tuples advances.

[1] In WarehousePG, an AO/CO table vacuum behaves differently than a heap table vacuum. Because WarehousePG stores the logical EOF for each segment file, it does not need to scan physical blocks after the logical EOF, and WarehousePG can truncate them. Because of this, for AO/CO tables, `heap_blks_vacuumed` could be either smaller or larger than `heap_blks_scanned`. Neither `heap_blks_vacuumed` nor `heap_blks_scanned` can be larger than `heap_blks_total`. Similarly, `heap_blks_scanned` can be less than or equal to `heap_blks_total` at the end of `VACUUM` for AO/CO tables - there is no need to scan blocks after the logical EOF of a segment file.

gp_stat_replication

The `gp_stat_replication` view contains replication statistics of the `walsender` process that is used for WarehousePG Write-Ahead Logging (WAL) replication when coordinator or segment mirroring is enabled.

column	type	references	description
`gp_segment_id`	integer		Unique identifier of a segment (or coordinator) instance.
`pid`	integer		Process ID of the `walsender` backend process.
`usesysid`	oid		User system ID that runs the `walsender` backend process.
`usename`	name		User name that runs the `walsender` backend process.
`application_name`	text		Client application name.
`client_addr`	inet		Client IP address.
`client_hostname`	text		Client host name.
`client_port`	integer		Client port number.
`backend_start`	timestamp		Operation start timestamp.
`backend_xmin`	xid		The current backend's `xmin` horizon.

`state`	text		`walsender` state. The value can be:
			`startup`
			`backup`
			`catchup`
			`streaming`

`sent_location`	text		`walsender` xlog record sent location.
`write_location`	text		`walreceiver` xlog record write location.
`flush_location`	text		`walreceiver` xlog record flush location.
`replay_location`	text		Coordinator standby or segment mirror xlog record replay location.
`sync_priority`	integer		Priority. The value is `1`.
`sync_state`	text		`walsender` synchronization state. The value is `sync`.
`sync_error`	text		`walsender` synchronization error. `none` if no error.

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gp_stat_resqueues

The `gp_stat_resqueues` view is a cluster-wide view that displays the `pg_stat_resqueues` information from every primary segment.

column	type	references	description
`gp_segment_id`	integer		Unique identifier of a segment (or coordinator) instance.
`queueid`	oid		The OID of the resource queue.
`queuename`	name		The name of the resource queue.
`n_queries_exec`	bigint		Number of queries submitted for execution from this resource queue.
`n_queries_wait`	bigint		Number of queries submitted to this resource queue that had to wait before they could run.
`elapsed_exec`	bigint		Total elapsed execution time for statements submitted through this resource queue.
`elapsed_wait`	bigint		Total elapsed time that statements submitted through this resource queue had to wait before they were run.

gp_stat_slru

The `gp_stat_slru` view is a cluster-wide view that displays the `pg_stat_slru` information from every primary segment.

column	type	references	description
`gp_segment_id`	integer		Unique identifier of a segment (or coordinator) instance.
`name`	text		Name of the SLRU.
`blks_zeroed`	bigint		Number of blocks zeroed during initializations.
`blks_hit`	bigint		Number of times disk blocks were found already in the SLRU, so that a read was not necessary (this only includes hits in the SLR, not the operating system's file system cache).
`blks_read`	bigint		Number of disk blocks read for this SLRU.
`blks_written`	biging		Number of disk blocks written for this SLRU.
`blks_exists`	biging		Number of blocks checked for existence for this SLRU.
`flushes`	bigint		Number of flushes of dirty data for this SLRU.
`truncates`	bigint		Number of truncates for this SLRU.
`stats_reset`	timestamp with time zone		Time at which these statistics were last reset.

This system view is summarized in the `gp_stat_slru_summary` system view.

gp_stat_ssl

The `gp_stat_ssl` view is a cluster-wide view that displays the `pg_stat_ssl` information from every primary segment.

column	type	references	description
`gp_segment_id`	integer		Unique identifier of a segment (or coordinator) instance.
`pid`	integer		Process ID of a backend or WAL sender process.
`ssl`	boolean		True if SSL is used on this connection
`version`	text		Version of SSL in use, or `NULL` if SSL is not in use on this connection.
`cipher`	text		Name of SSL cipher in use, or `NULL` if SSL is not in use on this connection.
`bits`	integer		Number of bits in the encryption algorithm used, or `NULL` if SSL is not used on this connection.
`client_dn`	text		Distinguished Name (DN) field from the client certificate used, or `NUL` L if no client certificate was supplied or if SSL is not in use on this connection. This field is truncated if the DN field is longer than `NAMEDATALEN` (64 characters in a standard build).
`client_serial`	numeric		Serial number of the client certificate, or `NULL` if no client certificate was supplied or if SSL is not in use on this connection. The combination of certificate serial number and certificate issuer uniquely identifies a certificate (unless the issuer erroneously reuses serial numbers).
`issuer_dn`	text		DN of the issuer of the client certificate, or `NULL` if no client certificate was supplied or if SSL is not in use on this connection. This field is truncated like `client_dn` is.

gp_stat_subscription

The `gp_stat_subscription` view is a cluster-wide view that displays the `pg_stat_subscription` information from every primary segment.

column	type	references	description
`gp_segment_id`	integer		Unique identifier of a segment (or coordinator) instance.
`subid`	oid		OID of the subscription.
`subname`	name		Name of the subscription.
`pid`	integer		Process ID of the subscription worker process.
`relid`	oid		OID of the relation that the worker is synchronizing; `NULL` for the main apply worker.

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column	type	references	description
`received_lsn`	pg_lsn		Last write-ahead log location received, the initial value of this field being `0`.
`last_msg_send_time`	timestamp with time zone		Send time of last message received from origin WAL sender.
`last_msg_receipt_time`	timestamp with time zone		Receipt time of last message received from origin WAL sender.
`latest_end_lsn`	pg_lsn		Last write-ahead log location reported to origin WAL sender.
`latest_end_time`	timestamp with time zone		Time of last write-ahead log location reported to origin WAL sender.

gp_stat_sys_indexes

The `gp_stat_sys_indexes` view is a cluster-wide view that displays the `pg_stat_sys_indexes` information from every primary segment. It shows the same information as `gp_stat_all_indexes` but filtered to show system indexes only.

This system view is summarized in the `gp_stat_sys_indexes_summary` system view.

gp_stat_sys_tables

The `gp_stat_sys_tables` view is a cluster-wide view that displays the `pg_stat_sys_tables` information from every primary segment. It shows the same information as `gp_stat_all_tables` but filtered to show system tables only.

gp_stat_user_functions

The `gp_stat_user_functions` view is a cluster-wide view that displays the `pg_stat_user_functions` information from every primary segment.

column	type	references	description
`gp_segment_id`	integer		Unique identifier of a segment (or coordinator) instance.
`funcid`	oid		OID of a function.
`schemaname`	name		Name of the schema this function is in.
`funcname`	name		Name of this function.
`calls`	bigint		Number of times this function has been called.
`total_time`	double precision		Total time spent in this function and all other functions called by it, in milliseconds.
`self_time`	double precision		Total time spent in this function itself, not including other functions called by it, in milliseconds.

This system view is summarized in the `gp_stat_user_functions_summary` system view.

gp_stat_user_indexes

The `gp_stat_user_indexes` view is a cluster-wide view that displays the `pg_stat_user_indexes` information from every primary segment. It shows the same information as `gp_stat_all_indexes` but filtered to show indexes on user tables only.

This system view is summarized in the `gp_stat_user_functions_summary` system view.

gp_stat_user_tables

The `gp_stat_user_tables` view is a cluster-wide view that displays the `pg_stat_user_tables` information from every primary segment. It shows the same information as `gp_stat_all_tables` but filtered to show only user tables.

gp_stat_wal

The `gp_stat_wal` view is a cluster-wide view that displays the `pg_stat_wal` information from every primary segment.

column	type	references	description
`gp_segment_id`	integer		Unique identifier of a segment (or coordinator) instance.
`wal_records`	bigint		Total number of WAL records generated.
`wal_fpw`	bigint		Total number of WAL full page images generated.
`wal_bytes`	numeric		Total amount of WAL generated in bytes.
`wal_buffers_full`	bigint		Number of times WAL data was written to disk because WAL buffers became full.
`wal_write`	bigint		Number of times WAL buffers were written out to disk.
`wal_sync`	bigint		Number of times WAL files were synced to disk.
`wal_write_time`	double precision		Total amount of time spent writing WAL buffers to disk, in milliseconds (if track_wal_io_timing is enabled, otherwise zero).
`wal_sync_time`	double precision		Total amount of time spent syncing WAL files to disk, in milliseconds (if `track_wal_io_timing` is enabled, otherwise zero).
`stats_reset`	timestamp with time zone		Time at which these statistics were last reset.

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This system view is summarized in the `gp_stat_wal_summary` system view.

gp_stat_wal_receiver

The `gp_stat_wal_receiver` view is a cluster-wide view that displays the `pg_stat_wal_receiver` information from every primary segment.

column	type	references	description
`gp_segment_id`	integer		Unique identifier of a segment (or coordinator) instance.
`pid`	integer		Process ID of the WAL receiver process.
`status`	text		Activity status of the WAL receiver process.
`receive_start_lsn`	pg_lsn		First write-ahead log location used when WAL receiver is started.
`receive_start_tli`	integer.		First timeline number used when WAL receiver is started.
`written_lsn`	pg_lsn.		Last write-ahead log location already received and written to disk, but not flushed. This should not be used for data integrity checks.
`flushed_lsn`	pg_lsn		Last write-ahead log location already received and flushed to disk, the initial value of this field being the first log location used when WAL receiver is started.
`received_tli`	integer		Timeline number of last write-ahead log location received and flushed to disk, the initial value of this field being the timeline number of the first log location used when WAL receiver is started.
`last_msg_send_time`	timestamp with time zone		Send time of last message received from origin WAL sender.
`last_msg_receipt_time`	timestamp with time zone		Receipt time of last message received from origin WAL sender.
`latest_end_lsn`	pg_lsn		Last write-ahead log location reported to origin WAL sender.
`latest_end_time`	timestamp with time zone		Time of last write-ahead log location reported to origin WAL sender.
`slot_name`	text		Replication slot name used by this WAL receiver.
`sender_host`	text		Host of the PostgreSQL instance this WAL receiver is connected to. This can be a host name, an IP address, or a directory path if the connection is via Unix socket. (The path case can be distinguished because it will always be an absolute path, beginning with `/.`).
`sender_port`	integer		Port number of the PostgreSQL instance this WAL receiver is connected to.
`conninfo`	text		Connection string used by this WAL receiver, with security-sensitive fields obfuscated.

gp_stat_xact_all_tables

The `gp_stat_xact_all_tables` view is a cluster-wide view that displays the `pg_stat_xact_all_tables` information from every primary segment. It shows the same information as `gp_stat_all_tables` but counts actions taken so far within the current transaction (which are not yet included in `gp_stat_all_tables` and related views). The columns for numbers of live and dead rows and vacuum and analyze actions are not present in this view.

This system view is summarized in the `gp_stat_xact_all_tables_summary` system view.

gp_stat_xact_sys_tables

The `gp_stat_xact_sys_tables` view is a cluster-wide view that displays the `pg_stat_xact_sys_tables` information from every primary segment. It shows the same information as `gp_stat_xact_all_tables` but filtered to show system tables only.

This system view is summarized in the `gp_stat_xact_sys_tables_summary` system view.

gp_stat_xact_user_functions

The `gp_stat_xact_user_functions` view is a cluster-wide view that displays the `pg_stat_xact_user_functions` information from every primary segment. It shows the same information as `gp_stat_xact_user_functions` but counts only calls during the current transaction (which are not yet included in `gp_stat_user_functions`).

This system view is summarized in the `gp_stat_xact_user_functions_summary` system view.

gp_stat_xact_user_tables

The `gp_stat_xact_user_tables` view is a cluster-wide view that displays the `pg_stat_xact_user_tables` information from every primary segment. It shows the same information as `gp_stat_xact_all_tables` but filtered to show user tables only.

This system view is summarized in the `gp_stat_xact_user_tables_summary` system view.

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gp_statio_all_indexes

The `gp_statio_all_indexes` view is a cluster-wide view that displays the `pg_statio_all_indexes` information from every primary segment.

column	type	references	description
`gp_segment_id`	integer		Unique identifier of a segment (or coordinator) instance.
`relid`	oid		OID of the table for this index.
`indexrelid`	oid		OID of this index.
`schemaname`	name		Name of the schema containing this index.
`relname`	name		Name of the table for this index.
`indexrelname`	name		Name of this index.
`idx_blks_read`	bigint		Number of disk blocks read from this index.
`idx_blks_hit`	bigint		Number of buffer hits in this index.

This system view is summarized in the `gp_statio_all_indexes_summary` system view.

gp_statio_all_sequences

The `gp_statio_all_sequences` view is a cluster-wide view that displays the `pg_statio_all_sequences` information from every primary segment.

column	type	references	description
`gp_segment_id`	integer		Unique identifier of a segment (or coordinator) instance.
`relid`	oid		OID of a sequence.
`schemaname`	name		Name of the schema this sequence is in.
`relname`	name		Name of this sequence.
`blks_read`	bigint		Number of disk blocks read from this sequence.
`blks_hit`	bigint		Number of buffer hits in this sequence.

This system view is summarized in the `gp_statio_all_sequences_summary` system view.

gp_statio_all_tables

The `gp_statio_all_tables` view is a cluster-wide view that displays the `pg_statio_all_tables` information from every primary segment.

column	type	references	description
`gp_segment_id`	integer		Unique identifier of a segment (or coordinator)
reli	oid	OID of a table.	
`schemaname`	name		Name of the schema containing this table.
`relname`	name		Name of this table.
`heap_blks_read`	bigint		Number of disk blocks read from this table.
`heap_blks_hit`	bigint		Number of buffer hits in this table.
`idx_blks_read`	bigint		Number of disk blocks read from all indexes on this table.
`idx_blks_hit`	bigint		Number of buffer hits in all indexes on this table.
`toast_blks_read`	bigint.		Number of disk blocks read from this table's TOAST table (if any).
`toast_blks_hit`	bigint		Number of buffer hits in this table's TOAST table (if any).
`tidx_blks_read`	bigint		Number of disk blocks read from this table's TOAST table indexes (if any).
`tidx_blks_hit`	bigint		Number of buffer hits in this table's TOAST table indexes (if any).

This system view is summarized in the `gp_statio_all_tables_summary` system view.

gp_statio_sys_indexes

The `gp_statio_sys_indexes` view is a cluster-wide view that displays the `pg_statio_sys_indexes` information from every primary segment. It shows the same information as `gp_statio_all_indexes` but filtered to show indexes on system tables only.

This system view is summarized in the `gp_statio_sys_indexes_summary` system view.

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gp_statio_sys_sequences

The `gp_statio_sys_sequences` view is a cluster-wide view that displays the `pg_statio_sys_sequences` information from every primary segment. It shows the same information as `gp_statio_all_sequences` but filtered to system sequences only.

This system view is summarized in the `gp_statio_sys_indexes_summary` system view.

gp_statio_sys_tables

The `gp_statio_sys_tables` view is a cluster-wide view that displays the `pg_statio_sys_tables` information from every primary segment. It shows the same information as `gp_statio_all_tables` but filtered to show system tables only.

This system view is summarized in the `gp_statio_sys_tables_summary` system view.

gp_statio_user_indexes

The `gp_statio_user_indexes` view is a cluster-wide view that displays the `pg_statio_user_indexes` information from every primary segment. It shows the same information as `gp_statio_all_indexes` but filtered to show indexes on user tables only.

This system view is summarized in the `gp_statio_sys_user_indexes_summary` system view.

gp_statio_user_sequences

The `gp_statio_user_sequences` view is a cluster-wide view that displays the `pg_statio_user_sequences` information from every primary segment. It shows the same information as `gp_statio_all_sequences` but filtered to show user sequences only.

This system view is summarized in the `gp_statio_sys_user_sequences_summary` system view.

gp_statio_user_tables

The `gp_statio_user_tables` view is a cluster-wide view that displays the `pg_statio_user_tables` information from every primary segment. It shows the same information as `gp_statio_all_tables` but filtered to show user tables only.

This system view is summarized in the `gp_statio_sys_user_tables_summary` system view.

gp_stats

The `gp_stats` view is a cluster-wide view that displays the `pg_stats` information from every primary segment.

column	type	references	description
`gp_segment_id`	integer		Unique identifier of a segment (or coordinator)
`schemaname`	name	pg_namespace.nspname	The name of the schema containing table.
`tablename`	name	pg_class.relname	The name of the table.
`attname`	name	pg_attribute.attname	The name of the column described by this row.
`inherited`	bool		If true, this row includes inheritance child columns, not just the values in the specified table.
`null_frac`	real		The fraction of column entries that are null.
`avg_width`	integer		The average width in bytes of column's entries.
`n_distinct`	real		If greater than zero, the estimated number of distinct values in the column. If less than zero, the negative of the number of distinct values divided by the number of rows. (The negated form is used when ANALYZE believes that the number of distinct values is likely to increase as the table grows; the positive form is used when the column seems to have a fixed number of possible values.) For example, `-1` indicates a unique column in which the number of distinct values is the same as the number of rows.
`most_common_vals`	anyarray		A list of the most common values in the column. (Null if no values seem to be more common than any others.)
`most_common_freqs`	real[]		A list of the frequencies of the most common values, i.e., number of occurrences of each divided by total number of rows. (Null when `most_common_vals` is.)
`histogram_bounds`	anyarray		A list of values that divide the column's values into groups of approximately equal population. The values in `most_common_vals`, if present, are omitted from this histogram calculation. (This column is null if the column data type does not have a `<` operator or if the `most_common_vals` list accounts for the entire population.)
`correlation`	real		Statistical correlation between physical row ordering and logical ordering of the column values. This ranges from -1 to +1. When the value is near -1 or +1, an index scan on the column will be estimated to be cheaper than when it is near zero, due to reduction of random access to the disk. (This column is null if the column data type does not have a `<` operator.)
`most_common_elems`	anyarray		A list of non-null element values most often appearing within values of the column. (Null for scalar types.)

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column	type	references	description
most_common_elem_freqs	real[]		A list of the frequencies of the most common element values, i.e., the fraction of rows containing at least one instance of the given value. Two or three additional values follow the per-element frequencies; these are the minimum and maximum of the preceding per-element frequencies, and optionally the frequency of null elements. (Null when most_common_elems is.)
element_count_histogram	real[]		A histogram of the counts of distinct non-null element values within the values of the column, followed by the average number of distinct non-null elements. (Null for scalar types.)

The maximum number of entries in the array fields can be controlled on a column-by-column basis using the `ALTER TABLE SET STATISTICS` command, or globally by setting the default_statistics_target run-time configuration parameter.

gp_stats_ext

The `gp_stats_ext` view is a cluster-wide view that displays the `pg_stats_ext` information from every primary segment.

column	type	references	description
gp_segment_id	integer		Unique identifier of a segment (or coordinator)
schemaname	name	pg_namespace.nspname	The name of the schema containing table.
tablename	name	pg_class.relname	The name of the table.
statistics_schemaname	name	pg_namespace.nspname	The name of the schema containing the extended statistic.
statistics_name	name	pg_statistic_ext.stxname	The name of the extended statistic.
statistics_owner	oid	pg_authid.oid	The owner of the extended statistic.
attnames	name[]	pg_attribute.attname	The names of the columns on which the extended statistics is defined.
kinds	text[]		The types of extended statistics enabled for this record.
n_distinct	pg_ndistinct		N-distinct counts for combinations of column values. If greater than zero, the estimated number of distinct values in the combination. If less than zero, the negative of the number of distinct values divided by the number of rows. (The negated form is used when `ANALYZE` believes that the number of distinct values is likely to increase as the table grows; the positive form is used when the column seems to have a fixed number of possible values.) For example, `-1` indicates a unique combination of columns in which the number of distinct combinations is the same as the number of rows.
dependencies	pg_dependencies		Functional dependency statistics.
most_common_vals	anyarray		A list of the most common values in the column. (Null if no combinations seem to be more common than any others.)
most_common_vals_null	anyarray		A list of NULL flags for the most combinations of values. (Null when `most_common_vals` is.)
most_common_freqs	real[]		A list of the frequencies of the most common combinations, i.e., number of occurrences of each divided by total number of rows. (Null when `most_common_vals` is.)
most_common_base_freqs	real[]		A list of the base frequencies of the most common combinations, i.e., product of per-value frequencies. (Null when `most_common_vals` is.)

The maximum number of entries in the array fields can be controlled on a column-by-column basis using the `ALTER TABLE SET STATISTICS` command, or globally by setting the default_statistics_target run-time configuration parameter.

pg_backend_memory_contexts

The `pg_backend_memory_contexts` system view displays all of the memory contexts in use by the server process attached to the current session.

`pg_backend_memory_contexts` contains one row for each memory context.

column	type	description
name	text	The name of the memory context.
ident	text	Identification information of the memory context. This field is truncated at 1024 bytes.
parent	text	The name of the parent of this memory context.
level	int4	The distance from `TopMemoryContext` in context tree.
total_bytes	int8	The total number of bytes allocated for this memory context.

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column	type	description
`total_nblocks`	int8	The total number of blocks allocated for this memory context.
`free_bytes`	int8	Free space in bytes.
`free_chunks`	int8	The total number of free chunks.
`used_bytes`	int8	Used space in bytes.

pg_cursors

The `pg_cursors` view lists the currently available cursors. Cursors can be defined in one of the following ways:

- via the DECLARE SQL statement
- via the Bind message in the frontend/backend protocol
- via the Server Programming Interface (SPI)

> **Note** WarehousePG does not support the definition, or access of, parallel retrieve cursors via SPI.

Cursors exist only for the duration of the transaction that defines them, unless they have been declared `WITH HOLD`. Non-holdable cursors are only present in the view until the end of their creating transaction.

> **Note** WarehousePG does not support holdable parallel retrieve cursors.

name	type	references	description
`name`	text		The name of the cursor.
`statement`	text		The verbatim query string submitted to declare this cursor.
`is_holdable`	boolean		`true` if the cursor is holdable (that is, it can be accessed after the transaction that declared the cursor has committed); `false` otherwise. > **Note** WarehousePG does not support holdable parallel retrieve cursors, this value is always `false` for such cursors.
`is_binary`	boolean		`true` if the cursor was declared `BINARY`; `false` otherwise.
`is_scrollable`	boolean		`true` if the cursor is scrollable (that is, it allows rows to be retrieved in a nonsequential manner); `false` otherwise. > **Note** WarehousePG does not support scrollable cursors, this value is always `false`.
`creation_time`	timestamptz		The time at which the cursor was declared.
`is_parallel`	boolean		`true` if the cursor was declared `PARALLEL RETRIEVE`; `false` otherwise.

pg_exttable

The `pg_exttable` system catalog view is used to track external tables and web tables created by the `CREATE EXTERNAL TABLE` command.

column	type	references	description
`reloid`	oid	pg_class.oid	The OID of this external table.
`urilocation`	text[]		The URI location(s) of the external table files.
`execlocation`	text[]		The ON segment locations defined for the external table.
`fmttype`	char		Format of the external table files: `t` for text, `c` for csv, or `b` for custom.
`fmtopts`	text		Formatting options of the external table files, such as the field delimiter, null string, escape character, etc.
`options`	text[]		The options defined for the external table.
`command`	text		The OS command to run when the external table is accessed.
`rejectlimit`	integer		The per segment reject limit for rows with errors, after which the load will fail.
`rejectlimittype`	char		Type of reject limit threshold: `r` for number of rows, or `p` for percent.
`logerrors`	bool		`1` to log errors, `0` to not.
`encoding`	text		The client encoding.
`writable`	boolean		`false` for readable external tables, `true` for writable external tables.

pg_matviews

The view `pg_matviews` provides access to information about each materialized view in the database.

column	type	references	description
`schemaname`	name	pg_namespace.nspname	Name of the schema containing the materialized view
`matviewname`	name	pg_class.relname	Name of the materialized view
`matviewowner`	name	pg_authid.rolname	Name of the materialized view's owner
`tablespace`	name	pg_tablespace.spcname	Name of the tablespace containing the materialized view (NULL if default for the database)
`hasindexes`	boolean		True if the materialized view has (or recently had) any indexes
`ispopulated`	boolean		True if the materialized view is currently populated
`definition`	text		Materialized view definition (a reconstructed `SELECT` command)

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pg_max_external_files

The `pg_max_external_files` view shows the maximum number of external table files allowed per segment host when using the external table `file` protocol.

column	type	references	description
`hostname`	name		The host name used to access a particular segment instance on a segment host.
`maxfiles`	bigint		Number of primary segment instances on the host.

pg_policies

The `pg_policies` view provides access to information about each row-level security policy in the database.

Column Name	Type	References	Description
`schemaname`	name	pg_namespace.nspname	The name of schema that contas the table the policy is on
`tablename`	name	pg_class.relname	The name of the table the policy is on
`policyname`	name	pg_policy.polname	The name of policy
`polpermissive`	text		Is the policy permissive or restrictive?
`roles`	name[]		The roles to which this policy applies
`cmd`	text		The command type to which the policy is applied
`qual`	text		The expression added to the security barrier qualifications for queries to which this policy applies
`with_check`	text		The expression added to the `WITH CHECK` qualifications for queries that attempt to add rows to this table

> **Note** Policies stored in `pg_policy` are applied only when `pg_class.relrowsecurity` is set for their table.

pg_resqueue_attributes

> **Note** The `pg_resqueue_attributes` view is valid only when resource queue-based resource management is active.

The `pg_resqueue_attributes` view allows administrators to see the attributes set for a resource queue, such as its active statement limit, query cost limits, and priority.

column	type	references	description
`rsqname`	name	pg_resqueue.rsqname	The name of the resource queue.
`resname`	text		The name of the resource queue attribute.
`resetting`	text		The current value of a resource queue attribute.
`restypid`	integer		System assigned resource type id.

pg_stat_activity

The `pg_stat_activity` view shows one row per server process with details about the associated user session and query. The columns that report data on the current query are available unless the parameter `stats_command_string` has been turned off. Furthermore, these columns are only visible if the user examining the view is a superuser or the same as the user owning the process being reported on.

The maximum length of the query text string stored in the column `query` can be controlled with the server configuration parameter `track_activity_query_size`.

column	type	references	description
`datid`	oid	pg_database.oid	Database OID
`datname`	name		Database name
`pid`	integer		Process ID of this backend
`sess_id`	integer		Session ID
`usesysid`	oid	pg_authid.oid	OID of the user logged into this backend
`usename`	name		Name of the user logged into this backend
`application_name`	text		Name of the application that is connected to this backend
`client_addr`	inet		IP address of the client connected to this backend. If this field is null, it indicates either that the client is connected via a Unix socket on the server machine or that this is an internal process such as autovacuum.
`client_hostname`	text		Host name of the connected client, as reported by a reverse DNS lookup of `client_addr`. This field will only be non-null for IP connections, and only when log_hostname is enabled.
`client_port`	integer		TCP port number that the client is using for communication with this backend, or -1 if a Unix socket is used
`backend_start`	timestamptz		Time backend process was started
`xact_start`	timestamptz		Transaction start time
`query_start`	timestamptz		Time query began execution
`state_change`	timestampz		Time when the `state` was last changed
`wait_event_type`	text		Type of event for which the backend is waiting

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column	type	references	description
wait_event	text		Wait event name if backend is currently waiting
state	text		Current overall state of this backend. Possible values are: - active : The backend is running a query. - idle : The backend is waiting for a new client command. - idle in transaction : The backend is in a transaction, but is not currently running a query. - idle in transaction (aborted) : This state is similar to idle in transaction, except one of the statements in the transaction caused an error. - fastpath function call : The backend is running a fast-path function. - disabled : This state is reported if track_activities is deactivated in this backend.
backend_xid	xid		The top-level transaction identifier of this backend, if any.
backend_xmin	xid		The current backend's xmin horizon.
query	text		Text of this backend's most recent query. If state is active this field shows the currently running query. In all other states, it shows the last query that was run.
backend_type	text		The type of the current backend.
rsgid	oid	pg_resgroup.oid	Resource group OID or 0 . See Note.
rsgname	text	pg_resgroup.rsgname	Resource group name or unknown . See Note.

> **Note** When resource groups are enabled. Only query dispatcher (QD) processes will have a rsgid and rsgname . Other server processes such as a query executer (QE) process or session connection processes will have a rsgid value of 0 and a rsgname value of unknown . QE processes are managed by the same resource group as the dispatching QD process.

pg_stat_all_indexes

The pg_stat_all_indexes view shows one row for each index in the current database that displays statistics about accesses to that specific index.

The pg_stat_user_indexes and pg_stat_sys_indexes views contain the same information, but filtered to only show user and system indexes respectively.

Column	Type	Description
relid	oid	OID of the table for this index
indexrelid	oid	OID of this index
schemaname	name	Name of the schema this index is in
relname	name	Name of the table for this index
indexrelname	name	Name of this index
idx_scan	bigint	Total number of index scans initiated on this index from all segment instances
idx_tup_read	bigint	Number of index entries returned by scans on this index
idx_tup_fetch	bigint	Number of live table rows fetched by simple index scans using this index

pg_stat_all_tables

The pg_stat_all_tables view shows one row for each table in the current database (including TOAST tables) to display statistics about accesses to that specific table.

The pg_stat_user_tables and pg_stat_sys_table views contain the same information, but filtered to only show user and system tables respectively.

Column	Type	Description
relid	oid	OID of a table
schemaname	name	Name of the schema that this table is in
relname	name	Name of this table
seq_scan	bigint	Total number of sequential scans initiated on this table from all segment instances
seq_tup_read	bigint	Number of live rows fetched by sequential scans
idx_scan	bigint	Total number of index scans initiated on this table from all segment instances
idx_tup_fetch	bigint	Number of live rows fetched by index scans
n_tup_ins	bigint	Number of rows inserted
n_tup_upd	bigint	Number of rows updated (includes HOT updated rows)
n_tup_del	bigint	Number of rows deleted
n_tup_hot_upd	bigint	Number of rows HOT updated (i.e., with no separate index update required)
n_live_tup	bigint	Estimated number of live rows
n_dead_tup	bigint	Estimated number of dead rows
n_mod_since_analyze	bigint	Estimated number of rows modified since this table was last analyzed
last_vacuum	timestamp with time zone	Last time this table was manually vacuumed (not counting VACUUM FULL)
last_autovacuum	timestamp with time zone	Last time this table was vacuumed by the autovacuum daemon
last_analyze	timestamp with time zone	Last time this table was manually analyzed

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Column	Type	Description
last_autoanalyze	timestamp with time zone	Last time this table was analyzed by the autovacuum daemon
vacuum_count	bigint	Number of times this table has been manually vacuumed (not counting VACUUM FULL)
autovacuum_count	bigint	Number of times this table has been vacuumed by the autovacuum daemon
analyze_count	bigint	Number of times this table has been manually analyzed
autoanalyze_count	bigint	Number of times this table has been analyzed by the autovacuum daemon

pg_stat_operations

The view pg_stat_operations shows details about the last operation performed on a database object (such as a table, index, view or database) or a global object (such as a role).

column	type	references	description
classname	text		The name of the system table in the pg_catalog schema where the record about this object is stored (pg_class =relations, pg_database =databases, pg_namespace =schemas, pg_authid =roles)
objname	name		The name of the object.
objid	oid		The OID of the object.
schemaname	name		The name of the schema where the object resides.
usestatus	text		The status of the role who performed the last operation on the object (CURRENT =a currently active role in the system, DROPPED =a role that no longer exists in the system, CHANGED =a role name that exists in the system, but has changed since the last operation was performed).
usename	name		The name of the role that performed the operation on this object.
actionname	name		The action that was taken on the object.
subtype	text		The type of object operated on or the subclass of operation performed.
statime	timestamptz		The timestamp of the operation. This is the same timestamp that is written to the WarehousePG server log files in case you need to look up more detailed information about the operation in the logs.

pg_stat_replication

The pg_stat_replication view contains metadata of the walsender process that is used for WarehousePG coordinator mirroring.

column	type	references	description
pid	integer		Process ID of WAL sender backend process.
usesysid	integer		User system ID that runs the WAL sender backend process
usename	name		User name that runs WAL sender backend process.
application_name	oid		Client application name.
client_addr	name		Client IP address.
client_hostname	text		The host name of the client machine.
client_port	integer		Client port number.
backend_start	timestamp		Operation start timestamp.
backend_xmin	xid		The current backend's xmin horizon.
state	text		WAL sender state. The value can be: startup backup catchup streaming
sent_location	text		WAL sender xlog record sent location.
write_location	text		WAL receiver xlog record write location.
flush_location	text		WAL receiver xlog record flush location.
replay_location	text		Standby xlog record replay location.
sync_priority	text		Priority. the value is 1.
sync_state	text		WAL sender synchronization state. The value is sync.

pg_stat_resqueues

> **Note** The pg_stat_resqueues view is valid only when resource queue-based resource management is active.

The pg_stat_resqueues view allows administrators to view metrics about a resource queue's workload over time. To allow statistics to be collected for this view, you must enable the stats_queue_level server configuration parameter on the WarehousePG coordinator instance. Enabling the collection of these metrics does incur a small performance penalty, as each statement submitted through a resource queue must be logged in the system catalog tables.

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column	type	references	description
queueid	oid		The OID of the resource queue.
queuename	name		The name of the resource queue.
n_queries_exec	bigint		Number of queries submitted for execution from this resource queue.
n_queries_wait	bigint		Number of queries submitted to this resource queue that had to wait before they could run.
elapsed_exec	bigint		Total elapsed execution time for statements submitted through this resource queue.
elapsed_wait	bigint		Total elapsed time that statements submitted through this resource queue had to wait before they were run.

pg_stat_slru

WarehousePG accesses certain on-disk information via SLRU (simple least-recently-used) caches. The pg_stat_slru view contains one row for each tracked SLRU cache, showing statistics about access to cached pages.

column	type	references	description
name	text		Name of the SLRU.
blks_zeroed	bigint		Number of blocks zeroed during initializations.
blks_hit	bigint		Number of times disk blocks were found already in the SLRU, so that a read was not necessary (this only includes hits in the SLR, not the operating system's file system cache).
blks_read	bigint		Number of disk blocks read for this SLRU.
blks_written	biging		Number of disk blocks written for this SLRU.
blks_exists	biging		Number of blocks checked for existence for this SLRU.
flushes	bigint		Number of flushes of dirty data for this SLRU.
truncates	bigint		Number of truncates for this SLRU.
stats_reset	timestamp with time zone		Time at which these statistics were last reset.

pg_stat_wal

The pg_stat_wal view shows data about the WAL activity of the cluster. It contains always a single row.

column	type	references	description
wal_records	bigint		Total number of WAL records generated.
wal_fpw	bigint		Total number of WAL full page images generated.
wal_bytes	numeric		Total amount of WAL generated in bytes.
wal_buffers_full	bigint		Number of times WAL data was written to disk because WAL buffers became full.
wal_write	bigint		Number of times WAL buffers were written out to disk.
wal_sync	bigint		Number of times WAL files were synced to disk.
wal_write_time	double precision		Total amount of time spent writing WAL buffers to disk, in milliseconds (if track_wal_io_timing is enabled, otherwise zero).
wal_sync_time	double precision		Total amount of time spent syncing WAL files to disk, in milliseconds (if track_wal_io_timing is enabled, otherwise zero).
stats_reset	timestamp with time zone		Time at which these statistics were last reset.

pg_stats

The pg_stats view provides access to the information stored in the pg_statistic catalog. This view allows access only to rows of pg_statistic that correspond to tables the user has permission to read, and therefore it is safe to allow public read access to this view.

pg_stats is also designed to present the information in a more readable format than the underlying catalog — at the cost that its schema must be extended whenever new slot types are defined fo pg_statistic .

column	type	references	description
schemaname	name	pg_namespace.nspname	The name of the schema containing table.
tablename	name	pg_class.relname	The name of the table.
attname	name	pg_attribute.attname	The name of the column described by this row.
inherited	bool		If true, this row includes inheritance child columns, not just the values in the specified table.
null_frac	real		The fraction of column entries that are null.
avg_width	integer		The average width in bytes of column's entries.
n_distinct	real		If greater than zero, the estimated number of distinct values in the column. If less than zero, the negative of the number of distinct values divided by the number of rows. (The negated form is used when ANALYZE believes that the number of distinct values is likely to increase as the table grows; the positive form is used when the column seems to have a fixed number of possible values.) For example, -1 indicates a unique column in which the number of distinct values is the same as the number of rows.

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column	type	references	description
most_common_vals	anyarray		A list of the most common values in the column. (Null if no values seem to be more common than any others.)
most_common_freqs	real[]		A list of the frequencies of the most common values, i.e., number of occurrences of each divided by total number of rows. (Null when most_common_vals is.)
histogram_bounds	anyarray		A list of values that divide the column's values into groups of approximately equal population. The values in most_common_vals, if present, are omitted from this histogram calculation. (This column is null if the column data type does not have a < operator or if the most_common_vals list accounts for the entire population.)
correlation	real		Statistical correlation between physical row ordering and logical ordering of the column values. This ranges from -1 to +1. When the value is near -1 or +1, an index scan on the column will be estimated to be cheaper than when it is near zero, due to reduction of random access to the disk. (This column is null if the column data type does not have a < operator.)
most_common_elems	anyarray		A list of non-null element values most often appearing within values of the column. (Null for scalar types.)
most_common_elem_freqs	real[]		A list of the frequencies of the most common element values, i.e., the fraction of rows containing at least one instance of the given value. Two or three additional values follow the per-element frequencies; these are the minimum and maximum of the preceding per-element frequencies, and optionally the frequency of null elements. (Null when most_common_elems is.)
element_count_histogram	real[]		A histogram of the counts of distinct non-null element values within the values of the column, followed by the average number of distinct non-null elements. (Null for scalar types.)

The maximum number of entries in the array fields can be controlled on a column-by-column basis using the ALTER TABLE SET STATISTICS command, or globally by setting the default_statistics_target run-time configuration parameter.

pg_stats_ext

The pg_stats view provides access to the information stored in the pg_statistic_ext and pg_statistic_ext_data catalog tables. This view allows access only to rows of pg_statistic_ext and pg_statistic_ext_data that correspond to tables the user has permission to read, and therefore it is safe to allow public read access to this view.

pg_stats_ext is also designed to present the information in a more readable format than the underlying catalogs — at the cost that its schema must be extended whenever new types of extended statistics are added to pg_statistic_ext.

column	type	references	description
schemaname	name	pg_namespace.nspname	The name of the schema containing table.
tablename	name	pg_class.relname	The name of the table.
statistics_schemaname	name	pg_namespace.nspname	The name of the schema containing the extended statistic.
statistics_name	name	pg_statistic_ext.stxname	The name of the extended statistic.
statistics_owner	oid	pg_authid.oid	The owner of the extended statistic.
attnames	name[]	pg_attribute.attname	The names of the columns on which the extended statistics is defined.
kinds	text[]		The types of extended statistics enabled for this record.
n_distinct	pg_ndistinct		N-distinct counts for combinations of column values. If greater than zero, the estimated number of distinct values in the combination. If less than zero, the negative of the number of distinct values divided by the number of rows. (The negated form is used when ANALYZE believes that the number of distinct values is likely to increase as the table grows; the positive form is used when the column seems to have a fixed number of possible values.) For example, -1 indicates a unique combination of columns in which the number of distinct combinations is the same as the number of rows.
dependencies	pg_dependencies		Functional dependency statistics.
most_common_vals	anyarray		A list of the most common values in the column. (Null if no combinations seem to be more common than any others.)
most_common_vals_null	anyarray		A list of NULL flags for the most combinations of values. (Null when most_common_vals is.)
most_common_freqs	real[]		A list of the frequencies of the most common combinations, i.e., number of occurrences of each divided by total number of rows. (Null when most_common_vals is.)
most_common_base_freqs	real[]		A list of the base frequencies of the most common combinations, i.e., product of per-value frequencies. (Null when most_common_vals is.)

The maximum number of entries in the array fields can be controlled on a column-by-column basis using the ALTER TABLE SET STATISTICS command, or globally by setting the default_statistics_target run-time configuration parameter.

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Summary Views

WarehousePG includes a number of summary views -- all related to collected statistics -- which aggregate across the WarehousePG cluster the metrics reported by their corresponding `gp_` view. For example, `gp_stat_archiver_summary` aggregates the metrics reported by `gp_stat_archiver`. These metrics are reported as sum, average, or last, depending on the column. For more information, see thesummary view code in Github.

The following is a list of summary views:

- gp_stat_all_indexes_summary
- gp_stat_all_tables_summary
- gp_stat_archiver_summary
- gp_stat_bgwriter_summary
- gp_stat_database_summary
- gp_stat_slru_summary
- gp_stat_progress_analyze_summary
- gp_stat_progress_basebackup_summary
- gp_stat_progress_cluster_summary
- gp_stat_progress_copy_summary
- gp_stat_progress_create_index_summary
- gp_stat_progress_vacuum_summary
- gp_stat_sys_indexes_summary
- gp_stat_user_functions_summary
- gp_stat_user_indexes_summary
- gp_stat_wal_summary
- gp_stat_xact_all_tables_summary
- gp_stat_xact_sys_tables_summary
- gp_stat_xact_user_functions_summary
- gp_stat_xact_user_tables_summary
- gp_statio_all_indexes_summary
- gp_statio_all_sequences_summary
- gp_statio_all_tables_summary
- gp_statio_sys_indexes_summary
- gp_statio_sys_sequences_summary
- gp_statio_sys_tables_summary
- gp_statio_user_indexes_summary
- gp_statio_user_sequences_summary
- gp_statio_user_tables_summary

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7.8.3 System Catalogs Definitions

System catalog table and view definitions in alphabetical order.

- foreign_data_wrapper_options
- foreign_data_wrappers
- foreign_server_options
- foreign_servers
- foreign_table_options
- foreign_tables
- gp_configuration_history
- gp_distributed_log
- gp_distributed_xacts
- gp_distribution_policy
- gpexpand.expansion_progress
- gp_endpoints
- gpexpand.status
- gpexpand.status_detail
- gp_fastsequence
- gp_id
- gp_partition_template
- gp_pgdatabase
- gp_resgroup_config
- gp_resgroup_status
- gp_resgroup_status_per_host
- gp_resqueue_status
- gp_segment_configuration
- gp_segment_endpoints
- gp_session_endpoints
- gp_stat_replication
- gp_transaction_log
- gp_version_at_initdb
- pg_aggregate
- pg_am
- pg_amop
- pg_amproc
- pg_appendonly
- pg_attrdef
- pg_attribute
- pg_attribute_encoding
- pg_auth_members
- pg_authid
- pg_available_extension_versions

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- pg_available_extensions
- pg_backend_memory_contexts
- pg_cast
- pg_class
- pg_compression
- pg_constraint
- pg_conversion
- pg_cursors
- pg_database
- pg_db_role_setting
- pg_depend
- pg_description
- pg_enum
- pg_extension
- pg_foreign_data_wrapper
- pg_foreign_server
- pg_foreign_table
- pg_index
- pg_inherits
- pg_language
- pg_largeobject
- pg_locks
- pg_matviews
- pg_max_external_files
- pg_namespace
- pg_opclass
- pg_operator
- pg_opfamily
- pg_partitioned_table
- pg_pltemplate
- pg_policies
- pg_policy
- pg_prepared_statements
- pg_proc
- pg_resgroup
- pg_resgroupcapability
- pg_resourcetype
- pg_resqueue
- pg_resqueue_attributes
- pg_resqueuecapability
- pg_rewrite
- pg_roles

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- pg_rules
- pg_shdepend
- pg_shdescription
- pg_stat_activity
- pg_stat_all_indexes
- pg_stat_all_tables
- pg_stat_last_operation
- pg_stat_last_shoperation
- pg_stat_operations
- pg_stat_replication
- pg_stat_resqueues
- pg_stat_slru
- pg_stat_wal
- pg_statistic
- pg_statistic_ext
- pg_statistic_ext_data
- pg_stats
- pg_stats_ext
- pg_tablespace
- pg_trigger
- pg_type
- pg_type_encoding
- pg_user_mapping
- pg_user_mappings
- user_mapping_options
- user_mappings

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7.8.3.1 foreign_data_wrapper_options

The `foreign_data_wrapper_options` view contains all of the otpions defined for foreign-data wrappers in the current database. WarehousePG displays only those foreign-data wrappers to which the current user has access (by way of being the owner or having some privilege).

column	type	references	description
`foreign_data_wrapper_catalog`	sql_identifier		Name of the database in which the foreign-data wrapper is defined (always the current database).
`foreign_data_wrapper_name`	sql_identifier		Name of the foreign-data wrapper.
`option_name`	sql_identifier		Name of an option.
`option_value`	character_data		Value of the option.

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7.8.3.2 foreign_data_wrappers

The `foreign_data_wrappers` view contains all foreign-data wrappers defined in the current database. WarehousePG displays only those foreign-data wrappers to which the current user has access (by way of being the owner or having some privilege).

column	type	references	description
`foreign_data_wrapper_catalog`	sql_identifier		Name of the database in which the foreign-data wrapper is defined (always the current database).
`foreign_data_wrapper_name`	sql_identifier		Name of the foreign-data wrapper.
`authorization_identifier`	sql_identifier		Name of the owner of the foreign server.
`library_name`	character_data		File name of the library that implements this foreign-data wrapper.
`foreign_data_wrapper_language`	character_data		Language used to implement the foreign-data wrapper.

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7.8.3.3 foreign_server_options

The `foreign_server_options` view contains all of the options defined for foreign servers in the current database. WarehousePG displays only those foreign servers to which the current user has access (by way of being the owner or having some privilege).

column	type	references	description
`foreign_server_catalog`	sql_identifier		Name of the database in which the foreign server is defined (always the current database).
`foreign_server_name`	sql_identifier		Name of the foreign server.
`option_name`	sql_identifier		Name of an option.
`option_value`	character_data		Value of the option.

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7.8.3.4 foreign_servers

The `foreign_servers` view contains all foreign servers defined in the current database. WarehousePG displays only those foreign servers to which the current user has access (by way of being the owner or having some privilege).

column	type	references	description
`foreign_server_catalog`	sql_identifier		Name of the database in which the foreign server is defined (always the current database).
`foreign_server_name`	sql_identifier		Name of the foreign server.
`foreign_data_wrapper_catalog`	sql_identifier		Name of the database in which the foreign-data wrapper used by the foreign server is defined (always the current database).
`foreign_data_wrapper_name`	sql_identifier		Name of the foreign-data wrapper used by the foreign server.
`foreign_server_type`	character_data		Foreign server type information, if specified upon creation.
`foreign_server_version`	character_data		Foreign server version information, if specified upon creation.
`authorization_identifier`	sql_identifier		Name of the owner of the foreign server.

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7.8.3.5 foreign_table_options

The `foreign_table_options` view contains all of the options defined for foreign tables in the current database. WarehousePG displays only those foreign tables to which the current user has access (by way of being the owner or having some privilege).

column	type	references	description
`foreign_table_catalog`	sql_identifier		Name of the database in which the foreign table is defined (always the current database).
`foreign_table_schema`	sql_identifier		Name of the schema that contains the foreign table.
`foreign_table_name`	sql_identifier		Name of the foreign table.
`option_name`	sql_identifier		Name of an option.
`option_value`	character_data		Value of the option.

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7.8.3.6 foreign_tables

The `foreign_tables` view contains all foreign tables defined in the current database. WarehousePG displays only those foreign tables to which the current user has access (by way of being the owner or having some privilege).

column	type	references	description
`foreign_table_catalog`	sql_identifier		Name of the database in which the foreign table is defined (always the current database).
`foreign_table_schema`	sql_identifier		Name of the schema that contains the foreign table.
`foreign_table_name`	sql_identifier		Name of the foreign table.
`foreign_server_catalog`	sql_identifier		Name of the database in which the foreign server is defined (always the current database).
`foreign_server_name`	sql_identifier		Name of the foreign server.

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7.8.3.7 gp_configuration_history

The `gp_configuration_history` table contains information about system changes related to fault detection and recovery operations. The `fts_probe` process logs data to this table, as do certain related management utilities such as `gprecoverseg` and `gpinitsystem`. For example, when you add a new segment and mirror segment to the system, records for these events are logged to `gp_configuration_history`.

The event descriptions stored in this table may be helpful for troubleshooting serious system issues in collaboration with support technicians.

This table is populated only on the coordinator. This table is defined in the `pg_global` tablespace, meaning it is globally shared across all databases in the system.

column	type	references	description
`time`	timestamp with time zone		Timestamp for the event recorded.
`dbid`	smallint	gp_segment_configuration.dbid	System-assigned ID. The unique identifier of a segment (or coordinator) instance.
`description`	text		Text description of the event.

For information about `gprecoverseg` and `gpinitsystem`, see the WarehousePG Utility Guide.

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7.8.3.8 gp_distribution_policy

The `gp_distribution_policy` table contains information about WarehousePG tables and their policy for distributing table data across the segments. This table is populated only on the coordinator. This table is not globally shared, meaning each database has its own copy of this table.

column	type	references	description
`localoid`	oid	pg_class.oid	The table object identifier (OID).
`policytype`	char		The table distribution policy: `p` - Partitioned policy. Table data is distributed among segment instances. `r` - Replicated policy. Table data is replicated on each segment instance.
`numsegments`	integer		The number of segment instances on which the table data is distributed.
`distkey`	int2vector	pg_attribute.attnum	The column number(s) of the distribution column(s).
`distclass`	oidvector	pg_opclass.oid	The operator class identifier(s) of the distribution column(s).

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7.8.3.9 gpexpand.status

The `gpexpand.status` table contains information about the status of a system expansion operation. Status for specific tables involved in the expansion is stored in gpexpand.status_detail.

In a normal expansion operation it is not necessary to modify the data stored in this table.

column	type	references	description

`status`	text		Tracks the status of an expansion operation. Valid values are:
			`SETUP`
			`SETUP DONE`
			`EXPANSION STARTED`
			`EXPANSION STOPPED`
			`COMPLETED`

`updated`	timestamp without time zone		Timestamp of the last change in status.

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7.8.3.10 gpexpand.status_detail

The `gpexpand.status_detail` table contains information about the status of tables involved in a system expansion operation. You can query this table to determine the status of tables being expanded, or to view the start and end time for completed tables.

This table also stores related information about the table such as the oid and disk size. Overall status information for the expansion is stored in gpexpand.status.

In a normal expansion operation it is not necessary to modify the data stored in this table.

column	type	references	description
`table_oid`	oid		OID of the table.
`dbname`	text		Name of the database to which the table belongs.
`fq_name`	text		Fully qualified name of the table.
`root_partition_oid`	oid		For a partitioned table, the OID of the root partition. Otherwise, `None`.
`rank`	int		Rank determines the order in which tables are expanded. The expansion utility will sort on rank and expand the lowest-ranking tables first.
`external_writable`	boolean		Identifies whether or not the table is an external writable table. (External writable tables require a different syntax to expand).
`status`	text		Status of expansion for this table. Valid values are: NOT STARTED IN PROGRESS COMPLETED NO LONGER EXISTS
`expansion_started`	timestamp without time zone		Timestamp for the start of the expansion of this table. This field is only populated after a table is successfully expanded.
`expansion_finished`	timestamp without time zone		Timestamp for the completion of expansion of this table.
`source_bytes`			The size of disk space associated with the source table. Due to table bloat in heap tables and differing numbers of segments after expansion, it is not expected that the final number of bytes will equal the source number. This information is tracked to help provide progress measurement to aid in duration estimation for the end-to-end expansion operation.

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7.8.3.11 gp_fastsequence

The `gp_fastsequence` table contains information about append-optimized and column-oriented tables. The `last_sequence` value indicates maximum row number currently used by the table.

column	type	references	description
`objid`	oid	pg_class.oid	Object id of the `pg_aoseg.pg_aocsseg_*` table used to track append-optimized file segments.
`objmod`	bigint		Object modifier.
`last_sequence`	bigint		The last sequence number used by the object.

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7.8.3.12 gp_id

The `gp_id` system catalog table identifies the WarehousePG cluster name and number of segments for the system. It also has `local` values for the particular database instance (segment or coordinator) on which the table resides. This table is defined in the `pg_global` tablespace, meaning it is globally shared across all databases in the system.

column	type	references	description
`gpname`	name		The name of this WarehousePG cluster.
`numsegments`	smallint		The number of segments in the WarehousePG cluster.
`dbid`	smallint		The unique identifier of this segment (or coordinator) instance.
`content`	smallint		The ID for the portion of data on this segment instance. A primary and its mirror will have the same content ID. For a segment the value is from 0-*N*-*1*, where *N* is the number of segments in WarehousePG. For the coordinator, the value is -1.

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7.8.3.13 gp_partition_template

The `gp_partition_template` system catalog table describes the relationship between a partitioned table and the sub-partition template defined at each level in the partition hierarchy.

> **Note** WarehousePG Data supports sub-partition templates only for partitioned tables that you create with the classic syntax.

Each sub-partition template has a dependency on the existence of a template at the next lower level of the hierarchy.

column	type	references	description
`relid`	oid	pg_class.oid	The object identifier of the root partitioned table.
`level`	smallint		The level of the partition in the hierarchy. The levels are numbered as follows: level `0` is the root partitioned table itself, level `1` represents the direct child/children of the root partitioned table, and so forth. The leaf partitions have the highest level number.
`template`	pg_node_tree		Expression representation of the sub-partition template defined for each partition at this level of the hierarchy.

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7.8.3.14 gp_segment_configuration

The `gp_segment_configuration` table contains information about mirroring and segment instance configuration.

column	type	references	description
`dbid`	smallint		Unique identifier of a segment (or coordinator) instance.
`content`	smallint		The content identifier for a segment instance. A primary segment instance and its corresponding mirror will always have the same content identifier. For a segment the value is from 0 to *N*-1, where *N* is the number of primary segments in the system. For the coordinator, the value is always -1.
`role`	char		The role that a segment is currently running as. Values are `p` (primary) or `m` (mirror).
`preferred_role`	char		The role that a segment was originally assigned at initialization time. Values are `p` (primary) or `m` (mirror).
`mode`	char		The synchronization status of a segment instance with its mirror copy. Values are `s` (Synchronized) or `n` (Not In Sync). > **Note** This column always shows `n` for the coordinator segment and `s` for the standby coordinator segment, but these values do not describe the synchronization state for the coordinator segment. Use gp_stat_replication to determine the synchronization state between the coordinator and standby coordinator.
`status`	char		The fault status of a segment instance. Values are `u` (up) or `d` (down).
`port`	integer		The TCP port the database server listener process is using.
`hostname`	text		The hostname of a segment host.
`address`	text		The hostname used to access a particular segment instance on a segment host. This value may be the same as `hostname` on systems that do not have per-interface hostnames configured.
`datadir`	text		Segment instance data directory.

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7.8.3.15 gp_version_at_initdb

The `gp_version_at_initdb` table is populated on the coordinator and each segment in the WarehousePG cluster. It identifies the version of WarehousePG used when the system was first initialized. This table is defined in the `pg_global` tablespace, meaning it is globally shared across all databases in the system.

column	type	references	description
`schemaversion`	smallint		Schema version number.
`productversion`	text		Product version number.

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7.8.3.16 pg_aggregate

The `pg_aggregate` table stores information about aggregate functions. An aggregate function is a function that operates on a set of values (typically one column from each row that matches a query condition) and returns a single value computed from all these values. Typical aggregate functions are `sum`, `count`, and `max`. Each entry in `pg_aggregate` is an extension of an entry in `pg_proc`. The `pg_proc` entry carries the aggregate's name, input and output data types, and other information that is similar to ordinary functions.

column	type	references	description
`aggfnoid`	regproc	pg_proc.oid	OID of the aggregate function
`aggkind`	char		Aggregate kind: `n` for *normal* aggregates, `o` for *ordered-set* aggregates, or `h` for *hypothetical-set* aggregates
`aggnumdirectargs`	smallint		Number of direct (non-aggregated) arguments of an ordered-set or hypothetical-set aggregate, counting a variadic array as one argument. If equal to `pronargs`, the aggregate must be variadic and the variadic array describes the aggregated arguments as well as the final direct arguments. Always zero for normal aggregates.
`aggtransfn`	regproc	pg_proc.oid	Transition function OID
`aggfinalfn`	regproc	pg_proc.oid	Final function OID (zero if none)
`aggcombinefn`	regproc	pg_proc.oid	Combine function OID (zero if none)
`aggserialfn`	regproc	pg_proc.oid	OID of the serialization function to convert transtype to `bytea` (zero if none)
`aggdeserialfn`	regproc	pg_proc.oid	OID of the deserialization function to convert `bytea` to transtype (zero if none)
`aggmtransfn`	regproc	pg_proc.oid	Forward transition function OID for moving-aggregate mode (zero if none)
`aggminvtransfn`	regproc	pg_proc.oid	Inverse transition function OID for moving-aggregate mode (zero if none)
`aggmfinalfn`	regproc	pg_proc.oid	Final function OID for moving-aggregate mode (zero if none)
`aggfinalextra`	bool		True to pass extra dummy arguments to `aggfinalfn`
`aggmfinalextra`	bool		True to pass extra dummy arguments to `aggmfinalfn`
`aggfinalmodify`	char		Indicates whether `aggfinalfn` modifies the transition state
`aggmfinalmodify`	char		Indicates whether `aggmfinalfn` modifies the transition state
`aggsortop`	oid	pg_operator.oid	Associated sort operator OID (zero if none)
`aggtranstype`	oid	pg_type.oid	Data type of the aggregate function's internal transition (state) data
`aggtransspace`	integer		Approximate average size (in bytes) of the transition state data, or zero to use a default estimate
`aggmtranstype`	oid	pg_type.oid	Data type of the aggregate function's internal transition (state) data for moving-aggregate mode (zero if none)
`aggmtransspace`	integer		Approximate average size (in bytes) of the transition state data for moving-aggregate mode, or zero to use a default estimate
`agginitval`	text		The initial value of the transition state. This is a text field containing the initial value in its external string representation. If this field is NULL, the transition state value starts out NULL.
`aggminitval`	text		The initial value of the transition state for moving- aggregate mode. This is a text field containing the initial value in its external string representation. If this field is NULL, the transition state value starts out NULL.
`aggrepsafeexec`	bool		True to specify that the aggregate can be safely executed on replicated slices. An order-agnostic aggregate would be considered safe in this context.

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7.8.3.17 pg_am

The `pg_am` table stores information about index access methods. There is one row for each index access method supported by the system.

column	type	references	description
`oid`	oid		Row identifier (hidden attribute; must be explicitly selected)
`amname`	name		Name of the access method
`amhandler`	regproc		OID of a handler function responsible for supplying information about the access method
`amtype`	char		`t` for table (including materialized views), `i` for index

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7.8.3.18 pg_amop

The `pg_amop` table stores information about operators associated with index access method operator classes. There is one row for each operator that is a member of an operator class.

An entry's `amopmethod` must match the `opfmethod` of its containing operator family (including `amopmethod` here is an intentional denormalization of the catalog structure for performance reasons). Also, `amoplefttype` and `amoprighttype` must match the `oprleft` and `oprright` fields of the referenced `pg_operator` entry.

column	type	references	description
`oid`	oid		Row identifier (hidden attribute; must be explicitly selected)
`amopfamily`	oid	pg_opfamily.oid	The operator family that this entry is for
`amoplefttype`	oid	pg_type.oid	Left-hand input data type of operator
`amoprighttype`	oid	pg_type.oid	Right-hand input data type of operator
`amopstrategy`	smallint		Operator strategy number
`amoppurpose`	char		Operator purpose, either `s` for search or `o` for ordering
`amopopr`	oid	pg_operator.oid	OID of the operator
`amopmethod`	oid	pg_am.oid	Index access method for the operator family
`amopsortfamily`	oid	pg_opfamily.oid	If an ordering operator, the B-tree operator family that this entry sorts according to; zero if a search operator

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7.8.3.19 pg_amproc

The `pg_amproc` table stores information about support procedures associated with index access method operator classes. There is one row for each support procedure belonging to an operator class.

column	type	references	description
`oid`	oid		Row identifier (hidden attribute; must be explicitly selected)
`amprocfamily`	oid	pg_opfamily.oid	The operator family this entry is for
`amproclefttype`	oid	pg_type.oid	Left-hand input data type of associated operator
`amprocrighttype`	oid	pg_type.oid	Right-hand input data type of associated operator
`amprocnum`	smallint		Support procedure number
`amproc`	regproc	pg_proc.oid	OID of the procedure

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7.8.3.20 pg_appendonly

The `pg_appendonly` table contains information about the storage options and other characteristics of append-optimized tables.

column	type	references	description
`relid`	oid		The table object identifier (OID) of the table.
`segrelid`	oid		Table on-disk segment file id.
`blkdirrelid`	oid		Block used for on-disk column-oriented table file.
`visimaprelid`	oid		Visibility map for the table.
`version`	smallint		AO relation version.

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7.8.3.21 pg_attrdef

The `pg_attrdef` table stores column default values. The main information about columns is stored in pg_attribute. Only columns that explicitly specify a default value (when the table is created or the column is added) will have an entry here.

column	type	references	description
`oid`	oid		The object ID
`adrelid`	oid	pg_class.oid	The table this column belongs to
`adnum`	smallint	pg_attribute.attnum	The number of the column
`adbin`	pg_node_tree		The internal representation of the column default value

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7.8.3.22 pg_attribute

The `pg_attribute` table stores information about table columns. There will be exactly one `pg_attribute` row for every column in every table in the database. (There will also be attribute entries for indexes, and all objects that have `pg_class` entries.) The term attribute is equivalent to column.

In a dropped column's `pg_attribute` entry, `atttypid` is reset to zero, but `attlen` and the other fields copied from `pg_type` are still valid. This arrangement is needed to address the situation where the dropped column's data type was later dropped, and so there is no `pg_type` row anymore. `attlen` and the other fields can be used to interpret the contents of a row of the table

column	type	references	description
`attrelid`	oid	pg_class.oid	The table this column belongs to.
`attname`	name		The column name.
`atttypid`	oid	pg_type.oid	The data type of this column.
`attstattarget`	integer		Controls the level of detail of statistics accumulated for this column by ANALYZE. A zero value indicates that no statistics should be collected. A negative value says to use the system default statistics target. The exact meaning of positive values is data type-dependent. For scalar data types, it is both the target number of "most common values" to collect, and the target number of histogram bins to create.
`attlen`	smallint		A copy of `pg_type.typlen` of this column's type.
`attnum`	smallint		The number of the column. Ordinary columns are numbered from 1 up. System columns, such as `ctid`, have (arbitrary) negative numbers.
`attndims`	integer		Number of dimensions, if the column is an array type; otherwise `0`. (Presently, the number of dimensions of an array is not enforced, so any nonzero value effectively means it is an array.)
`attcacheoff`	integer		Always `-1` in storage, but when loaded into a row descriptor in memory this may be updated to cache the offset of the attribute within the row.
`atttypmod`	integer		Records type-specific data supplied at table creation time (for example, the maximum length of a `varchar` column). It is passed to type-specific input functions and length coercion functions. The value will generally be `-1` for types that do not need it.
`attbyval`	boolean		A copy of `pg_type.typbyval` of this column's type.
`attstorage`	char		Normally a copy of `pg_type.typstorage` of this column's type. For TOAST-able data types, this can be altered after column creation to control storage policy.
`attalign`	char		A copy of `pg_type.typalign` of this column's type.
`attnotnull`	boolean		This represents a not-null constraint.
`atthasdef`	boolean		This column has a default expression or generation expression, in which case there will be a corresponding entry in the `pg_attrdef` catalog that actually defines the value. (Check `attgenerated` to determine whether this is a default or a generation expression.)
`atthasmissing`	boolean		This column has a value which is used where the column is entirely missing from the row, as happens when a column is added with a non-volatile `DEFAULT` value after the row is created. The actual value used is stored in the `attmissingval` column.
`attidentity`	char		If a zero byte (''), then not an identity column. Otherwise, `a` = generated always, `d` = generated by default.
`attgenerated`	char		If a zero byte (''), then not a generated column. Otherwise, `s` = stored. (Other values might be added in the future.)
`attisdropped`	boolean		This column has been dropped and is no longer valid. A dropped column is still physically present in the table, but is ignored by the parser and so cannot be accessed via SQL.
`attislocal`	boolean		This column is defined locally in the relation. Note that a column may be locally defined and inherited simultaneously.
`attinhcount`	integer		The number of direct ancestors this column has. A column with a nonzero number of ancestors cannot be dropped nor renamed.
`attcollation`	oid	pg_collation.oid	The defined collation of the column, or zero if the is not of a collatable data type.
`attacl`	aclitem[]		Column-level access privileges, if any have been granted specifically on this column.
`attoptions`	text[]		Attribute-level options, as "keyword=value" strings.
`attfdwoptions`	text[]		Attribute-level foreign data wrapper options, as "keyword=value" strings.
`attmissingval`	anyarray		This column has a one element array containing the value used when the column is entirely missing from the row, as happens when the column is added with a non-volatile `DEFAULT` value after the row is created. The value is only used when `atthasmissing` is `true`. If there is no value the column is null.

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7.8.3.23 pg_attribute_encoding

The `pg_attribute_encoding` system catalog table contains column storage information.

column	type	modifers	storage	description
`attrelid`	oid	not null	plain	Foreign key to `pg_attribute.attrelid`
`attnum`	smallint	not null	plain	Foreign key to `pg_attribute.attnum`
`filenum`	smallint	not null	plain	Shorthand for the file range assigned to the column
`lastrownums`	bigint		extended	The last row number of each segfile when this attribute is added.
`attoptions`	text [ ]		extended	The options

For a column with `filenum = f`, the column files on disk use the suffix `(f - 1)*128 to f*128 - 1`. For example:

- Column with `filenum = 1` has files `relfilenode`, `relfilenode.1` .. `relfilenode.127`.
- Column with `filenum = 2` has files `relfilenode.128`, `relfilenode.129` .. `relfilenode.255`.
- Column with `filenum = 3` has files `relfilenode.256`, `relfilenode.257` .. `relfilenode.383`.

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7.8.3.24 pg_auth_members

The `pg_auth_members` system catalog table shows the membership relations between roles. Any non-circular set of relationships is allowed. Because roles are system-wide, `pg_auth_members` is shared across all databases of a WarehousePG cluster.

column	type	references	description
`roleid`	oid	pg_authid.oid	ID of the parent-level (group) role
`member`	oid	pg_authid.oid	ID of a member role
`grantor`	oid	pg_authid.oid	ID of the role that granted this membership
`admin_option`	boolean		True if role member may grant membership to others

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7.8.3.25 pg_authid

The `pg_authid` table contains information about database authorization identifiers (roles). A role subsumes the concepts of users and groups. A user is a role with the `rolcanlogin` flag set. Any role (with or without `rolcanlogin`) may have other roles as members. See pg_auth_members.

Since this catalog contains passwords, it must not be publicly readable. pg_roles is a publicly readable view on `pg_authid` that blanks out the password field.

Because user identities are system-wide, `pg_authid` is shared across all databases in a WarehousePG cluster: there is only one copy of `pg_authid` per system, not one per database.

column	type	references	description
`oid`	oid		Row identifier
`rolname`	name		Role name
`rolsuper`	boolean		Role has superuser privileges
`rolinherit`	boolean		Role automatically inherits privileges of roles it is a member of
`rolcreaterole`	boolean		Role may create more roles
`rolcreatedb`	boolean		Role may create databases
`rolcanlogin`	boolean		Role may log in. That is, this role can be given as the initial session authorization identifier
`rolreplication`	boolean		Role is a replication role. That is, this role can initiate streaming replication and set/unset the system backup mode using `pg_start_backup` and `pg_stop_backup`.
`rolbypassrls`	boolean		Roles bypasses every row-level security policy.
`rolconnlimit`	int4		For roles that can log in, this sets maximum number of concurrent connections this role can make. `-1` means no limit
`rolpassword`	text		Password (possibly encrypted); NULL if none. If the password is encrypted, this column will begin with the string `md5` followed by a 32-character hexadecimal MD5 hash. The MD5 hash will be the user's password concatenated to their user name. For example, if user `joe` has password `xyzzy`, WarehousePG will store the md5 hash of `xyzzyjoe`. WarehousePG assumes that a password that does not follow that format is unencrypted.
`rolvaliduntil`	timestamptz		Password expiry time (only used for password authentication); NULL if no expiration
`rolresqueue`	oid		Object ID of the associated resource queue ID in *pg_resqueue*
`rolcreaterextgpfd`	boolean		Privilege to create read external tables with the `gpfdist` or `gpfdists` protocol
`rolcreaterexhttp`	boolean		Privilege to create read external tables with the `http` protocol
`rolcreatewextgpfd`	boolean		Privilege to create write external tables with the `gpfdist` or `gpfdists` protocol
`rolresgroup`	oid		Object ID of the associated resource group ID in *pg_resgroup*

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7.8.3.26 pg_available_extension_versions

The `pg_available_extension_versions` view lists the specific extension versions that are available for installation. The pg_extension system catalog table shows the extensions currently installed.

The view is read only.

column	type	description
`name`	name	Extension name.
`version`	text	Version name.
`installed`	boolean	`True` if this version of this extension is currently installed, `False` otherwise.
`superuser`	boolean	`True` if only superusers are allowed to install the extension, `False` otherwise.
`relocatable`	boolean	`True` if extension can be relocated to another schema, `False` otherwise.
`schema`	name	Name of the schema that the extension must be installed into, or `NULL` if partially or fully relocatable.
`requires`	name[]	Names of prerequisite extensions, or `NULL` if none
`comment`	text	Comment string from the extension control file.

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7.8.3.27 pg_available_extensions

The `pg_available_extensions` view lists the extensions that are available for installation. The *pg_extension* system catalog table shows the extensions currently installed.

The view is read only.

column	type	description
`name`	name	Extension name.
`default_version`	text	Name of default version, or `NULL` if none is specified.
`installed_version`	text	Currently installed version of the extension, or `NULL` if not installed.
`comment`	text	Comment string from the extension control file.

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7.8.3.28 pg_cast

The `pg_cast` table stores data type conversion paths, both built-in paths and those defined with `CREATE CAST`.

Note that `pg_cast` does not represent every type conversion known to the system, only those that cannot be deduced from some generic rule. For example, casting between a domain and its base type is not explicitly represented in `pg_cast`. Another important exception is that "automatic I/O conversion casts", those performed using a data type's own I/O functions to convert to or from `text` or other string types, are not explicitly represented in `pg_cast`.

The cast functions listed in `pg_cast` must always take the cast source type as their first argument type, and return the cast destination type as their result type. A cast function can have up to three arguments. The second argument, if present, must be type `integer`; it receives the type modifier associated with the destination type, or `-1` if there is none. The third argument, if present, must be type `boolean`; it receives `true` if the cast is an explicit cast, `false` otherwise.

It is legitimate to create a `pg_cast` entry in which the source and target types are the same, if the associated function takes more than one argument. Such entries represent 'length coercion functions' that coerce values of the type to be legal for a particular type modifier value.

When a `pg_cast` entry has different source and target types and a function that takes more than one argument, the entry converts from one type to another and applies a length coercion in a single step. When no such entry is available, coercion to a type that uses a type modifier involves two steps, one to convert between data types and a second to apply the modifier.

column	type	references	description
`oid`	oid		The object ID.
`castsource`	oid	pg_type.oid	OID of the source data type.
`casttarget`	oid	pg_type.oid	OID of the target data type.
`castfunc`	oid	pg_proc.oid	The OID of the function to use to perform this cast. Zero is stored if the cast method does not require a function.
`castcontext`	char		Indicates what contexts the cast may be invoked in. `e` means only as an explicit cast (using `CAST` or `::` syntax). `a` means implicitly in assignment to a target column, as well as explicitly. `i` means implicitly in expressions, as well as the other cases*.*
`castmethod`	char		Indicates how the cast is performed: `f` - The function identified in the `castfunc` field is used. `i` - The input/output functions are used. `b` - The types are binary-coercible, and no conversion is required.

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7.8.3.29 pg_class

The system catalog table `pg_class` catalogs tables and most everything else that has columns or is otherwise similar to a table. This includes indexes (see also pg_index), sequences, views, materialized views, composite types, and TOAST tables. Below, when we mean all of these kinds of objects we speak of "relations". Not all columns are meaningful for all relation types.

column	type	references	description
`oid`	oid		Row identifier
`relname`	name		Name of the table, index, view, etc.
`relnamespace`	oid	pg_namespace.oid	The object identifier of the namespace (schema) that contains this relation
`reltype`	oid	pg_type.oid	The object identifier of the data type that corresponds to this table's row type, if any (zero for indexes, which have no `pg_type` entry)
`reloftype`	oid	pg_type.oid	For typed tables, the object identifier of the underlying composite type, zero for all other relations
`relowner`	oid	pg_authid.oid	Owner of the relation
`relam`	oid	pg_am.oid	If this is a table or an index, the access method used (heap, B-tree, hash, etc.)
`relfilenode`	oid		Name of the on-disk file of this relation; zero means this is a "mapped" relation whose disk file name is determined by low-level state
`reltablespace`	oid	pg_tablespace.oid	The tablespace in which this relation is stored. If zero, the database's default tablespace is implied. (Not meaningful if the relation has no on-disk file.)
`relpages`	int4		Size of the on-disk representation of this table in pages (of size `BLCKSZ`). This is only an estimate used by the planner. It is updated by `VACUUM`, `ANALYZE`, and a few DDL commands such as `CREATE INDEX`.
`reltuples`	float4		Number of rows in the table. This is only an estimate used by the planner. It is updated by `VACUUM`, `ANALYZE`, and a few DDL commands such as `CREATE INDEX`.
`relallvisible`	int4		Number of pages that are marked all-visible in the table's visibility map. This is only an estimate used by the planner. It is updated by `VACUUM`, `ANALYZE`, and a few DDL commands such as `CREATE INDEX`.
`reltoastrelid`	oid	pg_class.oid	The object identifier of the TOAST table associated with this table, `0` if none. The TOAST table stores large attributes "out of line" in a secondary table.
`relhasindex`	boolean		True if this is a table and it has (or recently had) any indexes.
`relisshared`	boolean		True if this table is shared across all databases in the system. Only certain system catalog tables (such as `pg_database`) are shared.
`relpersistence`	char		The type of object persistence: `p` = heap or append-optimized permanent table, `u` = unlogged temporary table, `t` = temporary table.
`relkind`	char		The type of object `r` = heap or append-optimized ordinary table, `i` = index, `S` = sequence, `t` = TOAST table, `v` = view, `m` = materialized view, `c` = composite type, `f` = foreign table, `p` = partitioned table, `I` = partitioned index, `u` = uncatalogued temporary heap table, `o` = internal append-optimized segment files and EOFs, `b` = append-only block directory, `M` = append-only visibility map.
`relnatts`	int2		Number of user columns in the relation (system columns not counted). There must be this many corresponding entries in `pg_attribute`. See also `pg_attribute.attnum`.
`relchecks`	int2		Number of `CHECK` constraints on the table; see pg_constraint catalog.
`relhasrules`	boolean		True if table has (or once had) rules; see pg_rewrite catalog.
`relhastriggers`	boolean		True if table has (or once had) triggers.
`relhassubclass`	boolean		True if table has (or once had) any inheritance children.
`relrowsecurity`	boolean		True if table has row level security enabled; see `pg_policy` catalog.
`relforcerowsecurity`	boolean		True if row level security (when enabled) will also apply to the table owner; see `pg_policy` catalog.
`relispopulated`	boolean		True if relation is populated (this is true for all relations other than some materialized views).
`relreplident`	char		Columns used to form "replica identity" for rows: `d` = default (primary key, if any), `n` = nothing, `f` = all columns, `i` = index with `indisreplident` set (same as nothing if the index used has been dropped).
`relispartition`	boolean		True if table or index is a partition.
`relrewrite`	oid	pg_class.oid	For new relations being written during a DDL operation that requires a table rewrite, this contains the object identifier of the original relation; otherwise 0. That state is only visible internally; this field should never contain anything other than 0 for a user-visible relation.
`relfrozenxid`	xid		All transaction IDs before this one have been replaced with a permanent (frozen) transaction ID in this table. This is used to track whether the table needs to be vacuumed in order to prevent transaction ID wraparound or to allow `pg_xact` to be shrunk. The value is `0` (`InvalidTransactionId`) if the relation is not a table or if the table does not require vacuuming to prevent transaction ID wraparound. The table still might require vacuuming to reclaim disk space.
`relminmxid`	xid		All multixact IDs before this one have been replaced by a transaction ID in this table. This is used to track whether the table needs to be vacuumed in order to prevent multixact ID wraparound or to allow `pg_multixact` to be shrunk. Zero (`InvalidMultiXactId`) if the relation is not a table.
`relacl`	aclitem[]		Access privileges assigned by `GRANT` and `REVOKE`.
`reloptions`	text[]		Access-method-specific options, as "keyword=value" strings.
`relpartbound`	pg_node_tree		If table is a partition (see `relispartition`), internal representation of the partition bound.

Several of the Boolean flags in `pg_class` are maintained lazily: they are guaranteed to be true if that's the correct state, but may not be reset to false immediately when the condition is no longer true. For example, `relhasindex`

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is set by `CREATE INDEX`, but it is never cleared by `DROP INDEX`. Instead, `VACUUM` clears `relhasindex` if it finds the table has no indexes. This arrangement avoids race conditions and improves concurrency.

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7.8.3.30 pg_compression

The `pg_compression` system catalog table describes the compression methods available.

column	type	modifers	storage	description
`compname`	name	not null	plain	Name of the compression
`compconstructor`	regproc	not null	plain	Name of compression constructor
`compdestructor`	regproc	not null	plain	Name of compression destructor
`compcompressor`	regproc	not null	plain	Name of the compressor
`compdecompressor`	regproc	not null	plain	Name of the decompressor
`compvalidator`	regproc	not null	plain	Name of the compression validator
`compowner`	oid	not null	plain	oid from pg_authid

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7.8.3.31 pg_constraint

The `pg_constraint` system catalog table stores check, primary key, unique, foreign key, and exclusion constraints on tables. (Column constraints are not treated specially. Every column constraint is equivalent to some table constraint.) Not-null constraints are represented in the pg_attribute catalog table. Check constraints on domains are stored here, too.

column	type	references	description
`oid`	oid		Row identifier
`conname`	name		Constraint name (not necessarily unique!)
`connamespace`	oid	pg_namespace.oid	The object identifier of the namespace (schema) that contains this constraint.
`contype`	char		`c` = check constraint, `f` = foreign key constraint, `p` = primary key constraint, `u` = unique constraint, `x` = exclusion constraint.
`condeferrable`	boolean		Is the constraint deferrable?
`condeferred`	boolean		Is the constraint deferred by default?
`convalidated`	boolean		Has the constraint been validated? Currently, can only be false for foreign keys and `CHECK` constraints.
`conrelid`	oid	pg_class.oid	The table this constraint is on; 0 if not a table constraint.
`contypid`	oid	pg_type.oid	The domain this constraint is on; 0 if not a domain constraint.
`conindid`	oid	pg_class.oid	The index supporting this constraint, if it's a unique, primary key, foreign key, or exclusion constraint; else 0
`conparentid`	oid	pg_constraint.oid	The corresponding constraint in the parent partitioned table, if this is a constraint in a partition; else 0
`confrelid`	oid	pg_class.oid	If a foreign key, the referenced table; else 0.
`confupdtype`	char		Foreign key update action code.
`confdeltype`	char		Foreign key deletion action code.
`confmatchtype`	char		Foreign key match type.
`conislocal`	boolean		This constraint is defined locally for the relation. Note that a constraint can be locally defined and inherited simultaneously.
`coninhcount`	integer		The number of direct inheritance ancestors this constraint has. A constraint with a nonzero number of ancestors cannot be dropped nor renamed.
`connoinherit`	boolean		This constraint is defined locally for the relation. It is a non-inheritable constraint.
`conkey`	smallint[]	pg_attribute.attnum	If a table constraint, list of columns which the constraint constrains.
`confkey`	smallint[]	pg_attribute.attnum	If a foreign key, list of the referenced columns.
`conpfeqop`	oid[]	pg_operator.oid	If a foreign key, list of the equality operators for PK = FK comparisons.
`conppeqop`	oid[]	pg_operator.oid	If a foreign key, list of the equality operators for PK = PK comparisons.
`conffeqop`	oid[]	pg_operator.oid	If a foreign key, list of the equality operators for FK = FK comparisons.
`conexclop`	oid[]	pg_operator.oid	If an exclusion constraint, list of the per-column exclusion operators.
`conbin`	pg_node_tree		If a check constraint, an internal representation of the expression. (It is recommended to use `pg_get_constraintdef()` to extract the definition of a check constraint.)

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7.8.3.32 pg_conversion

The `pg_conversion` system catalog table describes the available encoding conversion procedures as defined by `CREATE CONVERSION`.

column	type	references	description
`oid`	oid		The object ID
`conname`	name		Conversion name (unique within a namespace)
`connamespace`	oid	pg_namespace.oid	The OID of the namespace (schema) that contains this conversion
`conowner`	oid	pg_authid.oid	Owner of the conversion
`conforencoding`	integer		Source encoding ID
`contoencoding`	integer		Destination encoding ID
`conproc`	regproc	pg_proc.oid	Conversion procedure
`condefault`	boolean		True if this is the default conversion

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7.8.3.33 pg_database

The `pg_database` system catalog table stores information about the available databases. Databases are created with the `CREATE DATABASE` SQL command. Unlike most system catalogs, `pg_database` is shared across all databases in the system. There is only one copy of `pg_database` per system, not one per database.

column	type	references	description
`oid`	oid		The object ID
`datname`	name		Database name
`datdba`	oid	pg_authid.oid	Owner of the database, usually the user who created it
`encoding`	integer		Character encoding for this database. `pg_encoding_to_char()` can translate this number to the encoding name
`datcollate`	name		`LC_COLLATE` for this database
`datctype`	name		`LC_CTYPE` for this database
`datistemplate`	boolean		If true then this database can be used in the `TEMPLATE` clause of `CREATE DATABASE` to create a new database as a clone of this one
`datallowconn`	boolean		If false then no one can connect to this database. This is used to protect the `template0` database from being altered
`datconnlimit`	integer		Sets the maximum number of concurrent connections that can be made to this database. `-1` means no limit
`datlastsysoid`	oid		Last system OID in the database
`datfrozenxid`	xid		All transaction IDs (XIDs) before this one have been replaced with a permanent (frozen) transaction ID in this database. This is used to track whether the database needs to be vacuumed in order to prevent transaction ID wraparound or to allow pg_xact to be shrunk. It is the minimum of the per-table *pg_class.relfrozenxid* values
`datminmxid`	xid		A *Multixact ID* is used to support row locking by multiple transactions. All multixact IDs before this one have been replaced with a transaction ID in this database. This is used to track whether the database needs to be vacuumed in order to prevent multixact ID wraparound or to allow `pg_multixact` to be shrunk. It is the minimum of the per-table *pg_class.relminmxid* values
`dattablespace`	oid	pg_tablespace.oid	The default tablespace for the database. Within this database, all tables for which *pg_class.reltablespace* is zero will be stored in this tablespace. All non-shared system catalogs will also be there
`datacl`	aclitem[]		Database access privileges as given by `GRANT` and `REVOKE`

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7.8.3.34 pg_db_role_setting

The `pg_db_role_setting` system catalog table records the default values of server configuration settings for each role and database combination.

There is a single copy of `pg_db_role_settings` per WarehousePG cluster. This system catalog table is shared across all databases.

You can view the server configuration settings for your WarehousePG cluster with `psql`'s `\drds` meta-command.

column	type	references	description
`setdatabase`	oid	pg_database.oid	The database to which the setting is applicable, or zero if the setting is not database-specific.
`setrole`	oid	pg_authid.oid	The role to which the setting is applicable, or zero if the setting is not role-specific.
`setconfig`	text[]		Per-database- and per-role-specific defaults for user-settable server configuration parameters.

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7.8.3.35 pg_depend

The `pg_depend` system catalog table records the dependency relationships between database objects. This information allows `DROP` commands to find which other objects must be dropped by `DROP CASCADE` or prevent dropping in the `DROP RESTRICT` case. See also pg_shdepend, which performs a similar function for dependencies involving objects that are shared across a WarehousePG cluster.

In all cases, a `pg_depend` entry indicates that the referenced object may not be dropped without also dropping the dependent object. However, there are several subtypes identified by `deptype`:

- **DEPENDENCY_NORMAL (n)** — A normal relationship between separately-created objects. The dependent object may be dropped without affecting the referenced object. The referenced object may only be dropped by specifying `CASCADE`, in which case the dependent object is dropped, too. Example: a table column has a normal dependency on its data type.
- **DEPENDENCY_AUTO (a)** — The dependent object can be dropped separately from the referenced object, and should be automatically dropped (regardless of `RESTRICT` or `CASCADE` mode) if the referenced object is dropped. Example: a named constraint on a table is made auto-dependent on the table, so that it will go away if the table is dropped.
- **DEPENDENCY_INTERNAL (i)** — The dependent object was created as part of creation of the referenced object, and is really just a part of its internal implementation. A direct `DROP` of the dependent object will be disallowed outright (issue a `DROP` against the referenced object instead). A `DROP` of the referenced object will be propagated through to drop the dependent object whether `CASCADE` is specified or not. If the dependent object has to be dropped due to a dependency on some other object being removed, its drop is converted to a drop of the referenced object, so that `NORMAL` and `AUTO` dependencies of the dependent object behave much like they were dependencies of the referenced object. Example: a view's `ON SELECT` rule is made internally dependent on the view, preventing it from being dropped while the view remains. Dependencies of the rule (such as tables it refers to) act as if they were dependencies of the view.
- **DEPENDENCY_PARTITION_PRI (P)**, **DEPENDENCY_PARTITION_SEC (S)** - The dependent object was created as part of creation of the referenced object, and is really just a part of its internal implementation; however, unlike `INTERNAL`, there is more than one such referenced object. The dependent object must not be dropped unless at least one of these referenced objects is dropped; if any one is, the dependent object should be dropped whether or not `CASCADE` is specified. Also unlike `INTERNAL`, a drop of some other object that the dependent object depends on does not result in automatic deletion of any partition-referenced object. Hence, if the drop does not cascade to at least one of these objects via some other path, it will be refused. (In most cases, the dependent object shares all its non-partition dependencies with at least one partition-referenced object, so that this restriction does not result in blocking any cascaded delete.) Primary and secondary partition dependencies behave identically except that the primary dependency is preferred for use in error messages; hence, a partition-dependent object should have one primary partition dependency and one or more secondary partition dependencies. Note that partition dependencies are made in addition to, not instead of, any dependencies the object would normally have. This simplifies `ATTACH/DETACH PARTITION` operations: the partition dependencies need only be added or removed. Example: a child partitioned index is made partition-dependent on both the partition table it is on and the parent partitioned index, so that it goes away if either of those is dropped, but not otherwise. The dependency on the parent index is primary, so that if the user tries to drop the child partitioned index, the error message will suggest dropping the parent index instead (not the table).
- **DEPENDENCY_EXTENSION (e)** - The dependent object is a member of the extension that is the referenced object (see pg_extension). The dependent object can be dropped only via `DROP EXTENSION` on the referenced object. Functionally, this dependency type acts the same as an `INTERNAL` dependency, but it's kept separate for clarity and to simplify pg_dump.
- **DEPENDENCY_AUTO_EXTENSION (x)** - The dependent object is not a member of the extension that is the referenced object (and so it should not be ignored by pg_dump), but it cannot function without the extension and should be auto-dropped if the extension is. The dependent object may be dropped on its own as well. Functionally this dependency type acts the same as an `AUTO` dependency, but it's kept separate for clarity and to simplify pg_dump.
- **DEPENDENCY_PIN (p)** — There is no dependent object; this type of entry is a signal that the system itself depends on the referenced object, and so that object must never be deleted. Entries of this type are created only by system initialization. The columns for the dependent object contain zeroes.

Note that it's quite possible for two objects to be linked by more than one `pg_depend` entry. For example, a child partitioned index would have both a partition-type dependency on its associated partition table, and an auto dependency on each column of that table that it indexes. This sort of situation expresses the union of multiple dependency semantics. A dependent object can be dropped without `CASCADE` if any of its dependencies satisfies its condition for automatic dropping. Conversely, all the dependencies' restrictions about which objects must be dropped together must be satisfied.

column	type	references	description
`classid`	oid	pg_class.oid	The object identifier of the system catalog the dependent object is in.
`objid`	oid	any OID column	The object identifier of the specific dependent object.
`objsubid`	integer		For a table column, this is the column number (the `objid` and `classid` refer to the table itself). For all other object types, this column is zero.
`refclassid`	oid	pg_class.oid	The object identifier of the system catalog the referenced object is in.
`refobjid`	oid	any OID column	The object identifier of the specific referenced object.
`refobjsubid`	integer		For a table column, this is the referenced column number (the `refobjid` and `refclassid` refer to the table itself). For all other object types, this column is zero.
`deptype`	char		The code defining the specific semantics of this dependency relationship.

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7.8.3.36 pg_description

The `pg_description` system catalog table stores optional descriptions (comments) for each database object. Descriptions can be manipulated with the `COMMENT` command and viewed with `psql`'s `\d` meta-commands. Descriptions of many built-in system objects are provided in the initial contents of `pg_description`. See also pg_shdescription, which performs a similar function for descriptions involving objects that are shared across a WarehousePG cluster.

column	type	references	description
`objoid`	oid	any OID column	The OID of the object this description pertains to.
`classoid`	oid	pg_class.oid	The OID of the system catalog this object appears in
`objsubid`	integer		For a comment on a table column, this is the column number. For all other object types, this column is zero.
`description`	text		Arbitrary text that serves as the description of this object.

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7.8.3.37 pg_enum

The `pg_enum` table contains entries matching enum types to their associated values and labels. The internal representation of a given enum value is actually the OID of its associated row in `pg_enum`. The OIDs for a particular enum type are guaranteed to be ordered in the way the type should sort, but there is no guarantee about the ordering of OIDs of unrelated enum types.

Column	Type	References	Description
`oid`	oid		The object ID
`enumtypid`	oid	pgtype.oid	The OID of the `pg_type` entry owning this enum value
`enumsortorder`	float4		The sort position of this enum value within its enum type
`enumlabel`	name		The textual label for this enum value

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7.8.3.38 pg_extension

The system catalog table `pg_extension` stores information about installed extensions.

column	type	references	description
`oid`	oid		The object ID
`extname`	name		Name of the extension
`extowner`	oid	pg_authid.oid	Owner of the extension
`extnamespace`	oid	pg_namespace.oid	Schema containing the extension exported objects
`extrelocatable`	boolean		True if the extension can be relocated to another schema
`extversion`	text		Version name for the extension
`extconfig`	oid[]	pg_class.oid	Array of `regclass` OIDs for the extension configuration tables, or `NULL` if none.
`extcondition`	text[]		Array of `WHERE` -clause filter conditions for the extension configuration tables, or `NULL` if none.

Unlike most catalogs with a namespace column, `extnamespace` does not imply that the extension belongs to that schema. Extension names are never schema-qualified. The `extnamespace` schema indicates the schema that contains most or all of the extension objects. If `extrelocatable` is `true` , then this schema must contain all schema-qualifiable objects that belong to the extension.

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7.8.3.39 pg_foreign_data_wrapper

The system catalog table `pg_foreign_data_wrapper` stores foreign-data wrapper definitions. A foreign-data wrapper is a mechanism by which you access external data residing on foreign servers.

column	type	references	description
`oid`	oid		The object ID
`fdwname`	name		Name of the foreign-data wrapper
`fdwowner`	oid	pg_authid.oid	Owner of the foreign-data wrapper
`fdwhandler`	oid	pg_proc.oid	A reference to a handler function that is responsible for supplying execution routines for the foreign-data wrapper. Zero if no handler is provided
`fdwvalidator`	oid	pg_proc.oid	A reference to a validator function that is responsible for checking the validity of the options provided to the foreign-data wrapper. This function also checks the options for foreign servers and user mappings using the foreign-data wrapper. Zero if no validator is provided
`fdwacl`	aclitem[]		Access privileges; see GRANT and REVOKE for details
`fdwoptions`	text[]		Foreign-data wrapper-specific options, as "keyword=value" strings

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7.8.3.40 pg_foreign_server

The system catalog table `pg_foreign_server` stores foreign server definitions. A foreign server describes a source of external data, such as a remote server. You access a foreign server via a foreign-data wrapper.

column	type	references	description
`oid`	oid		The object ID
`srvname`	name		Name of the foreign server
`srvowner`	oid	pg_authid.oid	Owner of the foreign server
`srvfdw`	oid	pg_foreign_data_wrapper.oid	OID of the foreign-data wrapper of this foreign server
`srvtype`	text		Type of server (optional)
`srvversion`	text		Version of the server (optional)
`srvacl`	aclitem[]		Access privileges; see GRANT and REVOKE for details
`srvoptions`	text[]		Foreign server-specific options, as "keyword=value" strings

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7.8.3.41 pg_foreign_table

The system catalog table `pg_foreign_table` contains auxiliary information about foreign tables. A foreign table is primarily represented by a `pg_class` entry, just like a regular table. Its `pg_foreign_table` entry contains the information that is pertinent only to foreign tables and not any other kind of relation.

column	type	references	description
`ftrelid`	oid	pg_class.oid	OID of the `pg_class` entry for this foreign table.
`ftserver`	oid	pg_foreign_server.oid	OID of the foreign server for this foreign table.
`ftoptions`	text[]		Foreign table options, as "keyword=value" strings.

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7.8.3.42 pg_index

The `pg_index` system catalog table contains part of the information about indexes. The rest is mostly in`pg_class`.

column	type	references	description
`indexrelid`	oid	pg_class.oid	The OID of the pg_class entry for this index
`indrelid`	oid	pg_class.oid	The OID of the pg_class entry for the table this index is for
`indnatts`	smallint		The number of columns in the index (duplicates pg_class.relnatts)
`indnkeyatts`	smallint		The number of key columns in the index
`indisunique`	boolean		If true, this is a unique index
`indisprimary`	boolean		If true, this index represents the primary key of the table. (indisunique should always be true when this is true.)
`indisexclusion`	boolean		If true, this index supports an exclusion constraint
indimmediate	boolean		If true, the uniqueness check is enforced immediately on insertion (irrelevant if `indisunique` is not true)
`indisclustered`	boolean		If true, the table was last clustered on this index via the `CLUSTER` command
`indisvalid`	boolean		If true, the index is currently valid for queries. False means the index is possibly incomplete: it must still be modified by `INSERT` / `UPDATE` operations, but it cannot safely be used for queries.
`indcheckxmin`	boolean		If true, queries must not use the index until the `xmin` of this `pg_index` row is below their `TransactionXmin` event horizon, because the table may contain broken HOT chains with incompatible rows that they can see
`indisready`	boolean		If true, the index is currently ready for inserts. False means the index must be ignored by `INSERT` / `UPDATE` operations
`indislive`	boolean		If false, the index is in process of being dropped, and should be ignored for all purposes
`indisreplident`	boolean		If true this index has been chosen as "replica identity" using `ALTER TABLE ... REPLICA IDENTITY USING INDEX ...`
`indkey`	int2vector	pg_attribute.attnum	This is an array of `indnatts` values that indicate which table columns this index indexes. For example a value of 1 3 would mean that the first and the third table columns make up the index key. A zero in this array indicates that the corresponding index attribute is an expression over the table columns, rather than a simple column reference.
`indcollation`	oidvector		For each column in the index key, this contains the OID of the collation to use for the index.
`indclass`	oidvector	pg_opclass.oid	For each column in the index key this contains the OID of the operator class to use
`indoption`	int2vector		This is an array of `indnatts` values that store per-column flag bits. The meaning of the bits is defined by the index's access method.
`indexprs`	pg_node_tree		Expression trees (in `nodeToString()` representation) for index attributes that are not simple column references. This is a list with one element for each zero entry in indkey. NULL if all index attributes are simple references.
`indpred`	pg_node_tree		Expression tree (in `nodeToString()` representation) for partial index predicate. NULL if not a partial index.

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7.8.3.43 pg_inherits

The `pg_inherits` system catalog table records information about table and index inheritance hierarchies. There is one entry for each direct parent-child table or index relationship in the database. (Indirect inheritance can be determined by following chains of entries.)

In WarehousePG, inheritance relationships are created by both the `INHERITS` clause (standalone inheritance) and the `PARTITION BY` clause (partitioned child table inheritance) of `CREATE TABLE`.

column	type	references	description
`inhrelid`	oid	pg_class.oid	The object identifier of the child table.
`inhparent`	oid	pg_class.oid	The object identifier of the parent table.
`inhseqno`	integer		If there is more than one direct parent for a child table (multiple inheritance), this number tells the order in which the inherited columns are to be arranged. The count starts at 1. Indexes can not have multiple inheritance, since they can only inherit when using declarative partitioning.

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7.8.3.44 pg_language

The `pg_language` system catalog table registers languages in which you can write functions or stored procedures. See CREATE LANGUAGE for more information about language handlers.

column	type	references	description
`oid`	oid		The object ID
`lanname`	name		Name of the language
`lanowner`	oid	pg_authid.oid	Owner of the language
`lanispl`	boolean		This is false for internal languages (such as SQL) and true for user-defined languages. Currently, `pg_dump` still uses this to determine which languages need to be dumped, but this may be replaced by a different mechanism in the future.
`lanpltrusted`	boolean		True if this is a trusted language, which means that it is believed not to grant access to anything outside the normal SQL execution environment. Only superusers may create functions in untrusted languages.
`lanplcallfoid`	oid	pg_proc.oid	For noninternal languages this references the language handler, which is a special function that is responsible for running all functions that are written in the particular language.
`laninline`	oid	pg_proc.oid	This references a function that is responsible for running inline anonymous code blocks (see the DO command). Zero if inline blocks are not supported.
`lanvalidator`	oid	pg_proc.oid	This references a language validator function that is responsible for checking the syntax and validity of new functions when they are created. Zero if no validator is provided.
`lanacl`	aclitem[]		Access privileges for the language

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7.8.3.45 pg_largeobject

Note WarehousePG does not support the PostgreSQL large object facility for streaming user data that is stored in large-object structures.

The `pg_largeobject` system catalog table holds the data making up 'large objects'. A large object is identified by an OID assigned when it is created. Each large object is broken into segments or 'pages' small enough to be conveniently stored as rows in `pg_largeobject`. The amount of data per page is defined to be `LOBLKSIZE` (which is currently `BLCKSZ`/4, or typically 8K).

Each row of `pg_largeobject` holds data for one page of a large object, beginning at byte offset (*pageno* `* LOBLKSIZE`) within the object. The implementation allows sparse storage: pages may be missing, and may be shorter than `LOBLKSIZE` bytes even if they are not the last page of the object. Missing regions within a large object read as zeroes.

column	type	references	description
`loid`	oid		Identifier of the large object that includes this page
`pageno`	integer		Page number of this page within its large object (counting from zero)
`data`	bytea		Actual data stored in the large object. This will never be more than `LOBLKSIZE` bytes and may be less.

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7.8.3.46 pg_locks

The `pg_locks` view provides access to information about the locks held by open transactions within WarehousePG.

`pg_locks` contains one row per active lockable object, requested lock mode, and relevant transaction. Thus, the same lockable object may appear many times if multiple transactions are holding or waiting for locks on it. An object with no current locks on it will not appear in the view at all.

There are several distinct types of lockable objects: whole relations (such as tables), individual pages of relations, individual tuples of relations, transaction IDs (both virtual and permanent IDs), and general database objects. Also, the right to extend a relation is represented as a separate lockable object.

column	type	references	description
`locktype`	text		Type of the lockable object: `relation`, `extend`, `page`, `tuple`, `transactionid`, `object`, `userlock`, `resource queue`, or `advisory`
`database`	oid	pg_database.oid	OID of the database in which the object exists, zero if the object is a shared object, or NULL if the object is a transaction ID
`relation`	oid	pg_class.oid	OID of the relation, or NULL if the object is not a relation or part of a relation
`page`	integer		Page number within the relation, or NULL if the object is not a tuple or relation page
`tuple`	smallint		Tuple number within the page, or NULL if the object is not a tuple
`virtualxid`	text		Virtual ID of a transaction, or NULL if the object is not a virtual transaction ID
`transactionid`	xid		ID of a transaction, or NULL if the object is not a transaction ID
`classid`	oid	pg_class.oid	OID of the system catalog containing the object, or NULL if the object is not a general database object
`objid`	oid	any OID column	OID of the object within its system catalog, or NULL if the object is not a general database object
`objsubid`	smallint		For a table column, this is the column number (the classid and objid refer to the table itself). For all other object types, this column is zero. NULL if the object is not a general database object
`virtualtransaction`	text		Virtual ID of the transaction that is holding or awaiting this lock
`pid`	integer		Process ID of the server process holding or awaiting this lock. NULL if the lock is held by a prepared transaction
`mode`	text		Name of the lock mode held or desired by this process
`granted`	boolean		True if lock is held, false if lock is awaited.
`fastpath`	boolean		True if lock was taken via fastpath, false if lock is taken via main lock table.
`mppsessionid`	integer		The id of the client session associated with this lock.
`mppiswriter`	boolean		Specifies whether the lock is held by a writer process.
`gp_segment_id`	integer		The WarehousePG segment id (`dbid`) where the lock is held.

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7.8.3.47 pg_namespace

The `pg_namespace` system catalog table stores namespaces. A namespace is the structure underlying SQL schemas: each namespace can have a separate collection of relations, types, etc. without name conflicts.

column	type	references	description
`oid`	oid		Row identifier (hidden attribute; must be explicitly selected)
`nspname`	name		Name of the namespace
`nspowner`	oid	pg_authid.oid	Owner of the namespace
`nspacl`	aclitem[]		Access privileges as given by `GRANT` and `REVOKE`

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7.8.3.48 pg_opclass

The `pg_opclass` system catalog table defines index access method operator classes. Each operator class defines semantics for index columns of a particular data type and a particular index access method. An operator class essentially specifies that a particular operator family is applicable to a particular indexable column data type. The set of operators from the family that are actually usable with the indexed column are those that accept the column's data type as their left-hand input.

An operator class's `opcmethod` must match the `opfmethod` of its containing operator family. Also, there must be no more than one `pg_opclass` row having `opcdefault` true for any given combination of `opcmethod` and `opcintype`.

The PostgreSQL Interfacing Extensions to Indexes documentation describes operator classes at length.

column	type	references	description
`oid`	oid		Row identifier (hidden attribute; must be explicitly selected)
`opcmethod`	oid	pg_am.oid	Index access method operator class is for
`opcname`	name		Name of this operator class
`opcnamespace`	oid	pg_namespace.oid	Namespace of this operator class
`opcowner`	oid	pg_authid.oid	Owner of the operator class
`opcfamily`	oid	pg_opfamily.oid	Operator family containing the operator class
`opcintype`	oid	pg_type.oid	Data type that the operator class indexes
`opcdefault`	boolean		True if this operator class is the default for the data type `opcintype`
`opckeytype`	oid	pg_type.oid	Type of data stored in index, or zero if same as `opcintype`

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7.8.3.49 pg_operator

The `pg_operator` system catalog table stores information about operators, both built-in and those defined by `CREATE OPERATOR`. Unused column contain zeroes. For example, `oprleft` is zero for a prefix operator.

column	type	references	description
`oid`	oid		Row identifier (hidden attribute, must be explicityly selected)
`oprname`	name		Name of the operator
`oprnamespace`	oid	pg_namespace.oid	The OID of the namespace that contains this operator
`oprowner`	oid	pg_authid.oid	Owner of the operator
`oprkind`	char		`b` = infix (both), `l` = prefix (left), `r` = postfix (right)
`oprcanmerge`	boolean		This operator supports merge joins
`oprcanhash`	boolean		This operator supports hash joins
`oprleft`	oid	pg_type.oid	Type of the left operand
`oprright`	oid	pg_type.oid	Type of the right operand
`oprresult`	oid	pg_type.oid	Type of the result
`oprcom`	oid	pg_operator.oid	Commutator of this operator, if any
`oprnegate`	oid	pg_operator.oid	Negator of this operator, if any
`oprcode`	regproc	pg_proc.oid	Function that implements this operator
`oprrest`	regproc	pg_proc.oid	Restriction selectivity estimation function for this operator
`oprjoin`	regproc	pg_proc.oid	Join selectivity estimation function for this operator

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7.8.3.50 pg_opfamily

The catalog `pg_opfamily` defines operator families. Each operator family is a collection of operators and associated support routines that implement the semantics specified for a particular index access method. Furthermore, the operators in a family are all compatible in a way that is specified by the access method. The operator family concept allows cross-data-type operators to be used with indexes and to be reasoned about using knowledge of access method semantics.

The majority of the information defining an operator family is not in its `pg_opfamily` row, but in the associated rows in pg_amop, pg_amproc, and pg_opclass.

Name	Type	References	Description
`oid`	oid		Row identifier (hidden attribute; must be explicitly selected)
`opfmethod`	oid	pg_am.oid	Index access method operator for this family
`opfname`	name		Name of this operator family
`opfnamespace`	oid	pg_namespace.oid	Namespace of this operator family
`opfowner`	oid	pg_authid.oid	Owner of the operator family

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7.8.3.51 pg_partitioned_table

The `pg_partitioned_table` system catalog stores information about how tables are partitioned.

column	type	references	description
`partrelid`	oid	pg_class.oid	The object identifier of the `pg_class` entry for this partitioned table.
`partstrat`	char		The partitioning strategy: `h` = hash partitioned table, `l` = list partitioned table, `r` = range partitioned table.
`partnatts`	smallint		The number of columns in the partition key.
`partdefid`	oid	pg_class.oid	The object identifier of the `pg_class` entry for the default partition of this partitioned table, or zero if this partitioned table does not have a default partition.
`partattrs`	int2vector	pg_attribute.attnum	An array of `partnatts` values that indicate which table columns are part of the partition key. For example, a value of `1 3` would mean that the first and the third table columns make up the partition key. A zero in this array indicates that the corresponding partition key column is an expression, rather than a simple column reference.
`partclass`	oidvector	pg_opclass.oid	For each column in the partition key, contains the object identifier of the operator class to use. See pg_opclass for details.
`partcollation`	oidvector	pg_opclass.oid	For each column in the partition key, contains the object identifier of the collation to use for partitioning, or zero if the column is not of a collatable data type.
`partexprs`	pg_node_tree		Expression trees (in `nodeToString()` representation) for partition key columns that are not simple column references. This list contains one element for each zero entry in `partattrs`. Null if all partition key columns are simple references. *WarehousePG classic partition syntax does not support specifying an expression in a partition key.*

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7.8.3.52 pg_pltemplate

The `pg_pltemplate` system catalog table stores template information for procedural languages. A template for a language allows the language to be created in a particular database by a simple `CREATE LANGUAGE` command, with no need to specify implementation details. Unlike most system catalogs, `pg_pltemplate` is shared across all databases of WarehousePG cluster: there is only one copy of `pg_pltemplate` per system, not one per database. This allows the information to be accessible in each database as it is needed.

There are not currently any commands that manipulate procedural language templates; to change the built-in information, a superuser must modify the table using ordinary `INSERT`, `DELETE`, or `UPDATE` commands.

column	type	references	description
`tmplname`	name		Name of the language this template is for
`tmpltrusted`	boolean		True if language is considered trusted
`tmpldbacreate`	boolean		True if language may be created by a database owner
`tmplhandler`	text		Name of call handler function
`tmplinline`	text		Name of anonymous-block handler function, or null if none
`tmplvalidator`	text		Name of validator function, or NULL if none
`tmpllibrary`	text		Path of shared library that implements language
`tmplacl`	aclitem[]		Access privileges for template (not yet implemented).

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7.8.3.53 pg_policy

The catalog `pg_policy` stores row level security policies for tables. A policy includes the kind of command that it applies to (possibly all commands), the roles that it applies to, the expression to be added as a security-barrier qualification to queries that include the table, and the expression to be added as a `WITH CHECK` option for queries that attempt to add new records to the table.

Column Name	Type	References	Description
`oid`	oid		The object ID
`polname`	name		The name of the policy
`polerelid`	oid	pg_class.oid	The table to which the policy applies
`polcmd`	char		The command type to which the policy is applied: `r` for `SELECT`, `a` for `INSERT`, `w` for `UPDATE`, `d` for `DELETE`, or `*` for all
`polpermissive`	boolean		Is the policy permissive or restrictive?
`polroles`	oid[]	pg_authid.oid	The roles to which the policy is applied
`polqual`	pg_node_tree		The expression tree to be added to the security barrier qualifications for queries that use the table
`polwithcheck`	pg_node_tree		The expression tree to be added to the `WITH CHECK` qualifications for queries that attempt to add rows to the table

> **Note** WarehousePG applies policies stored in `pg_policy` only when `pg_class.relrowsecurity` is set for their table.

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7.8.3.54 pg_prepared_statements

The `pg_prepared_statements` view displays all of the prepared statements that are available in the current session. See PREPARE for more information about prepared statements.

`pg_prepared_statements` contains one row for each prepared statement. Rows are added to the view when a new prepared statement is created and removed when a prepared statement is released (for example, with the DEALLOCATE command).

The `pg_prepared_statements` view is read-only.

name	type	description
`name`	text	The identifier of the prepared statement.
`statement`	text	The query string submitted by the client to create this prepared statement. For prepared statements created via SQL, this is the `PREPARE` statement submitted by the client. For prepared statements created via the frontend/backend protocol, this is the text of the prepared statement itself.
`prepare_time`	timestamptz	The time at which the prepared statement was created.
`parameter_types`	regtype[]	The expected parameter types for the prepared statement in the form of an array of `regtype`. The object identifier corresponding to an element of this array can be obtained by casting the `regtype` value to `oid`.
`from_sql`	boolean	`true` if the prepared statement was created via the `PREPARE` SQL command, `false` if the statement was prepared via the frontend/backend protocol.

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7.8.3.55 pg_proc

The `pg_proc` system catalog table stores information about functions (or procedures), both built-in functions and those defined by `CREATE FUNCTION`. The table contains data for aggregate and window functions as well as plain functions. If `proisagg` is true, there should be a matching row in `pg_aggregate`.

For compiled functions, both built-in and dynamically loaded, `prosrc` contains the function's C-language name (link symbol). For all other currently-known language types, `prosrc` contains the function's source text. `probin` is unused except for dynamically-loaded C functions, for which it gives the name of the shared library file containing the function.

column	type	references	description
`oid`	oid		Row identifier (hidden attribute; must be explicitly selected).
`proname`	name		Name of the function.
`pronamespace`	oid	pg_namespace.oid	The OID of the namespace that contains this function.
`proowner`	oid	pg_authid.oid	Owner of the function.
`prolang`	oid	pg_language.oid	Implementation language or call interface of this function.
`procost`	float4		Estimated execution cost (in cpu_operator_cost units); if `proretset` is `true`, identifies the cost per row returned.
`prorows`	float4		Estimated number of result rows (zero if not `proretset`).
`provariadic`	oid	pg_type.oid	Data type of the variadic array parameter's elements, or zero if the function does not have a variadic parameter.
`prosupport`	regproc	pg_proc.oid	Planner support function for this function
`prokind`	char		`f` for a normal function, `p` for a procedure, `a` for an aggregate function, or `w` for a window function
`prosecdef`	boolean		Function is a security definer (for example, a 'setuid' function).
`proleakproof`	boolean		The function has no side effects. No information about the arguments is conveyed except via the return value. Any function that might throw an error depending on the values of its arguments is not leak-proof.
`proisstrict`	boolean		Function returns NULL if any call argument is NULL. In that case the function will not actually be called at all. Functions that are not strict must be prepared to handle NULL inputs.
`proretset`	boolean		Function returns a set (multiple values of the specified data type).
`provolatile`	char		Tells whether the function's result depends only on its input arguments, or is affected by outside factors. `i` = *immutable* (always delivers the same result for the same inputs), `s` = *stable* (results (for fixed inputs) do not change within a scan), or `v` = *volatile* (results may change at any time or functions with side-effects).
`proparallel`	char		Indicates whether a function can be safely run in a parallel backend, or only in non-parallel mode
`pronargs`	smallint		Number of arguments.
`pronargdefaults`	smallint		Number of arguments that have default values.
`prorettype`	oid	pg_type.oid	Data type of the return value, or null for a procedure.
`proargtypes`	oidvector	pg_type.oid	An array with the data types of the function arguments. This includes only input arguments (including `INOUT` and `VARIADIC` arguments), and thus represents the call signature of the function.
`proallargtypes`	oid[]	pg_type.oid	An array with the data types of the function arguments. This includes all arguments (including `OUT` and `INOUT` arguments); however, if all of the arguments are `IN` arguments, this field will be null. Note that subscripting is 1-based, whereas for historical reasons `proargtypes` is subscripted from 0.
`proargmodes`	char[]		An array with the modes of the function arguments: `i` = `IN`, `o` = `OUT`, `b` = `INOUT`, `v` = `VARIADIC`. If all the arguments are IN arguments, this field will be null. Note that subscripts correspond to positions of `proallargtypes`, not `proargtypes`.
`proargnames`	text[]		An array with the names of the function arguments. Arguments without a name are set to empty strings in the array. If none of the arguments have a name, this field will be null. Note that subscripts correspond to positions of `proallargtypes` not `proargtypes`.
`proargdefaults`	pg_node_tree		Expression trees (in `nodeToString()` representation) for default argument values. This is a list with `pronargdefaults` elements, corresponding to the last N input arguments (i.e., the last N `proargtypes` positions). If none of the arguments have defaults, this field will be null.
`protrftypes`	oid[]		Types for which to apply transforms
`prosrc`	text		This tells the function handler how to invoke the function. It might be the actual source code of the function for interpreted languages, a link symbol, a file name, or just about anything else, depending on the implementation language/call convention.
`probin`	text		Additional information about how to invoke the function. Again, the interpretation is language-specific.
`proconfig`	text[]		Function's local settings for run-time configuration variables.
`proacl`	aclitem[]		Access privileges for the function as given by `GRANT` / `REVOKE`.
`proexeclocation`	char		Where the function runs when it is invoked: `m` - coordinator only, `a` - any segment instance, `s` - all segment instances, `i` - initplan.

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7.8.3.56 pg_resgroup

> **Note** The `pg_resgroup` system catalog table is valid only when resource group-based resource management is active.

The `pg_resgroup` system catalog table contains information about WarehousePG resource groups, which are used for managing concurrent statements, CPU, and memory resources. This table, defined in the `pg_global` tablespace, is globally shared across all databases in the system.

column	type	references	description
`oid`	oid		The object ID
`rsgname`	name		The name of the resource group.
`parent`	oid		Unused; reserved for future use.

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7.8.3.57 pg_resgroupcapability

Note The `pg_resgroupcapability` system catalog table is valid only when resource group-based resource management is active.

The `pg_resgroupcapability` system catalog table contains information about the capabilities and limits of defined WarehousePG resource groups. You can join this table to thepg_resgroup table by resource group object ID.

The `pg_resgroupcapability` table, defined in the `pg_global` tablespace, is globally shared across all databases in the system.

column	type	references	description
`resgroupid`	oid	`pg_resgroup.oid`	The object ID of the associated resource group.
`reslimittype`	smallint	``	The resource group limit type: 1 - Concurrency 2 - CPU_MAX_WEIGHT 3 - CPU_WEIGHT 4 - CPUSET 5 - MEMORY_QUOTA 6 - MIN_COST 7 - IO_LIMIT
`value`	opaque type		The specific value set for the resource limit referenced in this record. This value has the fixed type `text`, and will be converted to a different data type depending upon the limit referenced.

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7.8.3.58 pg_resourcetype

The `pg_resourcetype` system catalog table contains information about the extended attributes that can be assigned to WarehousePG resource queues. Each row details an attribute and inherent qualities such as its default setting, whether it is required, and the value to deactivate it (when allowed).

This table is populated only on the coordinator. This table is defined in the `pg_global` tablespace, meaning it is globally shared across all databases in the system.

column	type	references	description
`oid`	oid		The object ID
`resname`	name		The name of the resource type
`restypid`	smallint		The resource type ID
`resrequired`	boolean		Whether the resource type is required for a valid resource queue
`reshasdefault`	boolean		Whether the resource type has a default value. When true, the default value is specified in reshasdefaultsetting.
`rescandisable`	boolean		Whether the type can be removed or deactivated. When true, the default value is specified in resdisabledsetting.
`resdefaultsetting`	text		Default setting for the resource type, when applicable
`resdisabledsetting`	text		The value that deactivates this resource type (when allowed)

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7.8.3.59 pg_resqueue

Note The `pg_resqueue` system catalog table is valid only when resource queue-based resource management is active.

The `pg_resqueue` system catalog table contains information about WarehousePG resource queues, which are used for the resource management feature. This table is populated only on the coordinator. This table is defined in the `pg_global` tablespace, meaning it is globally shared across all databases in the system.

column	type	references	description
`oid`	oid		The object id
`rsqname`	name		The name of the resource queue
`rsqcountlimit`	real		The active query threshold of the resource queue
`rsqcostlimit`	real		The query cost threshold of the resource queue
`rsqovercommit`	boolean		Allows queries that exceed the cost threshold to run when the system is idle
`rsqignorecostlimit`	real		The query cost limit of what is considered a 'small query'. Queries with a cost under this limit will not be queued and run immediately.

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7.8.3.60 pg_resqueuecapability

> **Note** The `pg_resqueuecapability` system catalog table is valid only when resource queue-based resource management is active.

The `pg_resqueuecapability` system catalog table contains information about the extended attributes, or capabilities, of existing WarehousePG resource queues. Only resource queues that have been assigned an extended capability, such as a priority setting, are recorded in this table. This table is joined to the pg_resqueue table by resource queue object ID, and to the pg_resourcetype table by resource type ID (`restypid`).

This table is populated only on the coordinator. This table is defined in the `pg_global` tablespace, meaning it is globally shared across all databases in the system.

column	type	references	description
`rsqueueid`	oid	`pg_resqueue.oid`	The object ID of the associated resource queue.
`restypid`	smallint	`pg_resourcetype.restypid`	The resource type, derived from the *pg_resqueuecapability* system table.
`resetting`	text		The specific value set for the capability referenced in this record. Depending on the actual resource type, this value may have different data types.

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7.8.3.61 pg_rewrite

The `pg_rewrite` system catalog table stores rewrite rules for tables and views. `pg_class.relhasrules` must be true if a table has any rules in this catalog.

column	type	references	description
`oid`	oid		The object ID
`rulename`	name		Rule name
`ev_class`	oid	pg_class.oid	The table this rule is for
`ev_type`	char		Event type that the rule is for: 1 = SELECT, 2 = UPDATE, 3 = INSERT, 4 = DELETE
`ev_enabled`	char		Controls in which session replication role mode the rule fires. Always O, rule fires in origin mode.
`is_instead`	boolean		True if the rule is an `INSTEAD` rule
`ev_qual`	pg_node_tree		Expression tree (in the form of a `nodeToString()` representation) for the rule's qualifying condition
`ev_action`	pg_node_tree		Query tree (in the form of a `nodeToString()` representation) for the rule's action

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7.8.3.62 pg_roles

The view `pg_roles` provides access to information about database roles. This is simply a publicly readable view of pg_authid that blanks out the password field. This view explicitly exposes the OID column of the underlying table, since that is needed to do joins to other catalogs.

column	type	references	description
`rolname`	name		Role name
`rolsuper`	bool		Role has superuser privileges
`rolinherit`	bool		Role automatically inherits privileges of roles it is a member of
`rolcreaterole`	bool		Role may create more roles
`rolcreatedb`	bool		Role may create databases
`rolcatupdate`	bool		Role may update system catalogs directly. (Even a superuser may not do this unless this column is true.)
`rolcanlogin`	bool		Role may log in. That is, this role can be given as the initial session authorization identifier
`rolconnlimit`	int4		For roles that can log in, this sets maximum number of concurrent connections this role can make. -1 means no limit
`rolpassword`	text		Not the password (always reads as ********)
`rolvaliduntil`	timestamptz		Password expiry time (only used for password authentication); NULL if no expiration
`rolconfig`	text[]		Role-specific defaults for run-time configuration variables
`rolresqueue`	oid	pg_resqueue.oid	Object ID of the resource queue this role is assigned to.
`oid`	oid	pg_authid.oid	Object ID of role
`rolcreaterextgpfd`	bool		Role may create readable external tables that use the gpfdist protocol.
`rolcreaterexthttp`	bool		Role may create readable external tables that use the http protocol.
`rolcreatewextgpfd`	bool		Role may create writable external tables that use the gpfdist protocol.
`rolresgroup`	oid	pg_resgroup.oid	Object ID of the resource group to which this role is assigned.

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7.8.3.63 pg_rules

The view `pg_rules` provides access to useful information about query rewrite rules.

The `pg_rules` view excludes the `ON SELECT` rules of views and materialized views; those can be seen in `pg_views` and `pg_matviews`.

column	type	references	description
`schemaname`	name	pg_namespace.nspname	Name of schema containing table
`tablename`	name	pg_class.relname	Name of table the rule is for
`rulename`	name	pg_rewrite.rulename	Name of rule
`definition`	text		Rule definition (a reconstructed creation command)

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7.8.3.64 pg_shdepend

The `pg_shdepend` system catalog table records the dependency relationships between database objects and shared objects, such as roles. This information allows WarehousePG to ensure that those objects are unreferenced before attempting to delete them. See also pg_depend, which performs a similar function for dependencies involving objects within a single database. Unlike most system catalogs, `pg_shdepend` is shared across all databases of WarehousePG cluster: there is only one copy of `pg_shdepend` per system, not one per database.

In all cases, a `pg_shdepend` entry indicates that the referenced object may not be dropped without also dropping the dependent object. However, there are several subflavors identified by `deptype`:

- **SHARED_DEPENDENCY_OWNER (o)** — The referenced object (which must be a role) is the owner of the dependent object.
- **SHARED_DEPENDENCY_ACL (a)** — The referenced object (which must be a role) is mentioned in the ACL (access control list) of the dependent object.
- **SHARED_DEPENDENCY_PIN (p)** — There is no dependent object; this type of entry is a signal that the system itself depends on the referenced object, and so that object must never be deleted. Entries of this type are created only by system initialization. The columns for the dependent object contain zeroes.

column	type	references	description
`dbid`	oid	pg_database.oid	The OID of the database the dependent object is in, or zero for a shared object.
`classid`	oid	pg_class.oid	The OID of the system catalog the dependent object is in.
`objid`	oid	any OID column	The OID of the specific dependent object.
`objsubid`	integer		For a table column, this is the column number. For all other object types, this column is zero.
`refclassid`	oid	pg_class.oid	The OID of the system catalog the referenced object is in (must be a shared catalog).
`refobjid`	oid	any OID column	The OID of the specific referenced object.
`deptype`	char		A code defining the specific semantics of this dependency relationship.

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7.8.3.65 pg_shdescription

The `pg_shdescription` system catalog table stores optional descriptions (comments) for shared database objects. Descriptions can be manipulated with the `COMMENT` command and viewed with `psql`'s `\d` meta-commands. See also pg_description, which performs a similar function for descriptions involving objects within a single database. Unlike most system catalogs, `pg_shdescription` is shared across all databases of a WarehousePG cluster: there is only one copy of `pg_shdescription` per system, not one per database.

column	type	references	description
`objoid`	oid	any OID column	The OID of the object this description pertains to.
`classoid`	oid	pg_class.oid	The OID of the system catalog this object appears in
`description`	text		Arbitrary text that serves as the description of this object.

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7.8.3.66 pg_stat_last_operation

The pg_stat_last_operation table contains metadata tracking information about database objects (tables, views, etc.).

column	type	references	description
`classid`	oid	pg_class.oid	OID of the system catalog containing the object.
`objid`	oid	any OID column	OID of the object within its system catalog.
`staactionname`	name		The action that was taken on the object.
`stasysid`	oid	pg_authid.oid	A foreign key to pg_authid.oid.
`stausename`	name		The name of the role that performed the operation on this object.
`stasubtype`	text		The type of object operated on or the subclass of operation performed.
`statime`	timestamp with timezone		The timestamp of the operation. This is the same timestamp that is written to the WarehousePG server log files in case you need to look up more detailed information about the operation in the logs.

The `pg_stat_last_operation` table contains metadata tracking information about operations on database objects. This information includes the object id, DDL action, user, type of object, and operation timestamp. WarehousePG updates this table when a database object is created, altered, truncated, vacuumed, analyzed, or partitioned, and when privileges are granted to an object.

If you want to track the operations performed on a specific object, use the `objid` value. Because the `stasubtype` value can identify either the type of object operated on or the subclass of operation performed, it is not a suitable parameter when querying the `pg_stat_last_operation` table.

The following example creates and replaces a view, and then shows how to use `objid` as a query parameter on the `pg_stat_last_operation` table.

```
testdb=# CREATE VIEW trial AS SELECT * FROM gp_segment_configuration;
CREATE VIEW
testdb=# CREATE OR REPLACE VIEW trial AS SELECT * FROM gp_segment_configuration;
CREATE VIEW
testdb=# SELECT * FROM pg_stat_last_operation WHERE objid='trial'::regclass::oid;
 classid | objid | staactionname | stasysid | stausename | stasubtype |            statime
---------+-------+---------------+----------+------------+------------+-------------------------------
  1259   | 24735 | CREATE        |       10 | gpadmin    | VIEW       | 2020-04-07 16:44:28.808811+00
  1259   | 24735 | ALTER         |       10 | gpadmin    | SET        | 2020-04-07 16:44:38.110615+00
(2 rows)
```

Notice that the `pg_stat_last_operation` table entry for the view `REPLACE` operation specifies the `ALTER` action (`staactionname`) and the `SET` subtype (`stasubtype`).

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7.8.3.67 pg_stat_last_shoperation

The pg_stat_last_shoperation table contains metadata tracking information about global objects (roles, tablespaces, etc.).

column	type	references	description
classid	oid	pg_class.oid	OID of the system catalog containing the object
objid	oid	any OID column	OID of the object within its system catalog
staactionname	name		The action that was taken on the object
stasysid	oid		The OID of the role that performed the operation in this object
stausename	name		The name of the role that performed the operation on this object
stasubtype	text		The type of object operated on or the subclass of operation performed
statime	timestamp with timezone		The timestamp of the operation. This is the same timestamp that is written to the WarehousePG server log files in case you need to look up more detailed information about the operation in the logs.

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7.8.3.68 pg_stat_operations

The view `pg_stat_operations` shows details about the last operation performed on a database object (such as a table, index, view or database) or a global object (such as a role).

column	type	references	description
`classname`	text		The name of the system table in the `pg_catalog` schema where the record about this object is stored (`pg_class` =relations, `pg_database` =databases, `pg_namespace` =schemas, `pg_authid` =roles)
`objname`	name		The name of the object.
`objid`	oid		The OID of the object.
`schemaname`	name		The name of the schema where the object resides.
`usestatus`	text		The status of the role who performed the last operation on the object (`CURRENT` =a currently active role in the system, `DROPPED` =a role that no longer exists in the system, `CHANGED` =a role name that exists in the system, but has changed since the last operation was performed).
`usename`	name		The name of the role that performed the operation on this object.
`actionname`	name		The action that was taken on the object.
`subtype`	text		The type of object operated on or the subclass of operation performed.
`statime`	timestamptz		The timestamp of the operation. This is the same timestamp that is written to the WarehousePG server log files in case you need to look up more detailed information about the operation in the logs.

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7.8.3.69 pg_statistic

The `pg_statistic` system catalog table stores statistical data about the contents of the database. Entries are created by ANALYZE and subsequently used by the query planner. Note that all the statistical data is inherently approximate, even assuming that it is up-to-date.

Normally, there is one entry, with `stainherit = false`, for each table column that has been analyzed. If the table has inheritance children, WarehousePG creates a second entry with `stainherit = true`. This row represents the column's statistics over the inheritance tree, for example, statistics for the data you would see with `SELECT column FROM table*`, whereas the `stainherit = false` row represents the results of `SELECT column FROM ONLY table`.

`pg_statistic` also stores statistical data about the values of index expressions. These are described as if they were actual data columns; in particular, `starelid` references the index. No entry is made for an ordinary non-expression index column, however, since it would be redundant with the entry for the underlying table column. Currently, entries for index expressions always have `stainherit = false`.

Since different kinds of statistics may be appropriate for different kinds of data, `pg_statistic` is designed not to assume very much about what sort of statistics it stores. Only extremely general statistics (such as nullness) are given dedicated columns in `pg_statistic`. Everything else is stored in slots, which are groups of associated columns whose content is identified by a code number in one of the slot's columns.

`pg_statistic` should not be readable by the public, since even statistical information about a table's contents should be considered sensitive. (Example: minimum and maximum values of a salary column). pg_stats is a publicly readable view on `pg_statistic` that only exposes information about those tables that are readable by the current user.

> **Caution** Diagnostic tools such as `gpsd` and `minirepro` collect sensitive information from `pg_statistic`, such as histogram boundaries, in a clear, readable form. Always review the output files of these utilities to ensure that the contents are acceptable for transport outside of the database in your organization.

column	type	references	description
`starelid`	oid	pg_class.oid	The table or index that the described column belongs to
`staattnum`	smallint	pg_attribute.attnum	The number of the described column
`stainherit`	boolean		If true, the statistics include inheritance child columns, not just the values in the specified relations.
`stanullfrac`	float4		The fraction of the column's entries that are null
`stawidth`	integer		The average stored width, in bytes, of nonnull entries
`stadistinct`	float4		The number of distinct nonnull data values in the column. A value greater than zero is the actual number of distinct values. A value less than zero is the negative of a multiplier for the number rows in the table (for example, a column in which about 80% of the values are nonnull and each nonnull value appears about twice on the average could be represented by `stadistinct` = -0.4). A zero value means the number of distinct values is unknown.
`stakind*N*`	integer		A code number indicating the kind of statistics stored in the `N` th slot of the `pg_statistic` row
`staop*N*`	oid	pg_operator.oid	An operator used to derive the statistics stored in the `N` th slot. For example, a histogram slot would show the `<` operator that defines the sort order of the data.
`stacoll*N*`	oid	pg_collation.oid	The collation used to derive the statistics stored in the `N` th slot. For example, a histogram slot for a collatable column would show the collation that defines the sort order of the data. Zero for noncollatable data.
`stanumbers*N*`	float4[]		Numerical statistics of the appropriate kind for the `N` th slot, or NULL if the slot kind does not involve numerical values.
`stavalues*N*`	anyarray		Column data values of the appropriate kind for the `N` th slot, or NULL if the slot kind does not store any data values. Each array's element values are actually of the specific column's data type, or a related type such as an array's element type, so there is no way to define these columns' type more specifically than `anyarray`.

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7.8.3.70 pg_statistic_ext

The `pg_statistic_ext` system catalog table holds definitions of extended planner statistics. Each row in this catalog corresponds to a *statistics object* created with CREATE STATISTICS.

column	type	references	description
`oid`	oid		The object ID
`stxrelid`	oid	pg_class.oid	The table containing the columns described by this object
`stxname`	name		The name of the statistics object
`stxnamespace`	oid	pg_namespace.oid	The object identifier of the namespace that contains this statistics object
`stxowner`	oid	pg_authid.oid	The owner of the statistics object
`stxkeys`	int2vector	pg_attribute.oid	An array of attribute numbers, indicating which table columns are covered by this statistics object; for example, a value of `1 3` would mean that the first and the third table columns are covered
`stxkind`	char[]		An array containing codes for the enabled statistics kinds; valid values are: `d` for n-distinct statistics, `f` for functional dependency statistics, and `m` for most common values (MCV) list statistics

The `pg_statistic_ext` entry is filled in completely during `CREATE STATISTICS`, but the actual statistical values are not computed then. Subsequent `ANALYZE` commands compute the desired values and populate an entry in the pg_statistic_ext_data catalog.

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7.8.3.71 pg_statistic_ext_data

The `pg_statistic_ext_data` system catalog table holds data for extended planner statistics defined in pg_statistic_ext. Each row in this catalog corresponds to a *statistics object* created with CREATE STATISTICS.

Like `pg_statistic`, `pg_statistic_ext_data` should not be readable by the public, since the contents might be considered sensitive. (Example: most common combinations of values in columns might be quite interesting.) pg_stats_ext is a publicly readable view on `pg_statistic_ext_data` (after joining with `pg_statistic_ext`) that only exposes information about those tables and columns that are readable by the current user.

column	type	references	description
`stxoid`	oid	pg_statistic_ext.oid	The extended statistic object containing the definition for this data.
`stxdndistinct`	pg_ndistinct		N-distinct counts, serialized as `pg_ndistinct` type.
`stxddependencies`	pg_dependencies		Functional dependency statistics, serialized as `pg_dependencies` type.
`stxdmcv`	pg_mcv_list		MCV (most-common values) list statistics, serialized as `pg_mcv_list` type.

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7.8.3.72 pg_tablespace

The `pg_tablespace` system catalog table stores information about the available tablespaces. Tables can be placed in particular tablespaces to aid administration of disk layout. Unlike most system catalogs, `pg_tablespace` is shared across all databases of a WarehousePG cluster: there is only one copy of `pg_tablespace` per system, not one per database.

column	type	references	description
`oid`	oid		The object ID
`spcname`	name		Tablespace name.
`spcowner`	oid	pg_authid.oid	Owner of the tablespace, usually the user who created it.
`spcacl`	aclitem[]		Tablespace access privileges.
`spcoptions`	text[]		Tablespace contentID locations.

Parent topic: System Catalogs Definitions

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7.8.3.73 pg_trigger

The `pg_trigger` system catalog table stores triggers on tables.

> **Note** WarehousePG does not support triggers.

column	type	references	description
`oid`	oid		The object ID
`tgrelid`	oid	*pg_class.oid* Note that WarehousePG does not enforce referential integrity.	The table this trigger is on.
`tgname`	name		Trigger name (must be unique among triggers of same table).
`tgfoid`	oid	*pg_proc.oid* Note that WarehousePG does not enforce referential integrity.	The function to be called.
`tgtype`	smallint		Bit mask identifying trigger conditions.
`tgenabled`	char		True if trigger is enabled.
`tgisinternal`	boolean		True if trigger is internally generated (usually, to enforce the constraint identified by tgconstraint).
`tgconstrrelid`	oid	*pg_class.oid* Note that WarehousePG does not enforce referential integrity.	The table referenced by an referential integrity constraint.
`tgconstrindid`	oid	*pg_class.oid*	The index supporting a unique, primary key, or referential integrity constraint.
`tgconstraint`	oid	*pg_constraint.oid*	The `pg_constraint` entry associated with the trigger, if any.
`tgdeferrable`	boolean		True if deferrable.
`tginitdeferred`	boolean		True if initially deferred.
`tgnargs`	smallint		Number of argument strings passed to trigger function.
`tgattr`	int2vector		Currently not used.
`tgargs`	bytea		Argument strings to pass to trigger, each NULL-terminated.
`tgqual`	pg_node_tree		Expression tree (in `nodeToString()` representation) for the trigger's `WHEN` condition, or null if none.
`tgoldtable`	name		The name of the old transition table, or NULL if none.
`tgnewtable`	name		The name of the new transition table, or NULL if none.

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7.8.3.74 pg_type

The `pg_type` system catalog table stores information about data types. Base types (scalar types) are created with `CREATE TYPE`, and domains with `CREATE DOMAIN`. A composite type is automatically created for each table in the database, to represent the row structure of the table. It is also possible to create composite types with `CREATE TYPE AS`.

column	type	references	description
`oid`	oid		Row identifier (hidden attribute; must be explicitly selected)
`typname`	name		Data type name
`typnamespace`	oid	pg_namespace.oid	The OID of the namespace that contains this type
`typowner`	oid	pg_authid.oid	Owner of the type
`typlen`	smallint		For a fixed-size type, `typlen` is the number of bytes in the internal representation of the type. But for a variable-length type, `typlen` is negative. `-1` indicates a 'varlena' type (one that has a length word), `-2` indicates a null-terminated C string.
`typbyval`	boolean		Determines whether internal routines pass a value of this type by value or by reference. `typbyval` had better be false if `typlen` is not 1, 2, or 4 (or 8 on machines where Datum is 8 bytes). Variable-length types are always passed by reference. Note that `typbyval` can be false even if the length would allow pass-by-value.
`typtype`	char		`b` for a base type, `c` for a composite type, `d` for a domain, `e` for an enum type, `p` for a pseudo-type, or `r` for a range type. See also `typrelid` and `typbasetype`.
`typcategory`	char		Arbitrary classification of data types that is used by the parser to determine which implicit casts should be preferred. SeeCategory Codes.
`typispreferred`	boolean		True if the type is a preferred cast target within its `typcategory`
`typisdefined`	boolean		True if the type is defined, false if this is a placeholder entry for a not-yet-defined type. When false, nothing except the type name, namespace, and OID can be relied on.
`typdelim`	char		Character that separates two values of this type when parsing array input. Note that the delimiter is associated with the array element data type, not the array data type.
`typrelid`	oid	pg_class.oid	If this is a composite type (see `typtype`), then this column points to the `pg_class` entry that defines the corresponding table. (For a free-standing composite type, the `pg_class` entry does not really represent a table, but it is needed anyway for the type's `pg_attribute` entries to link to.) Zero for non-composite types.
`typelem`	oid	pg_type.oid	If not `0` then it identifies another row in `pg_type`. The current type can then be subscripted like an array yielding values of type `typelem`. A "true" array type is variable length (`typlen` = `-1`), but some fixed-length (`typlen` > `0`) types also have nonzero `typelem`, for example `name` and `point`. If a fixed-length type has a `typelem` then its internal representation must be some number of values of the `typelem` data type with no other data. Variable-length array types have a header defined by the array subroutines.
`typarray`	oid	pg_type.oid	If not 0, identifies another row in `pg_type`, which is the "true" array type having this type as its element. Use `pg_type.typarray` to locate the array type associated with a specific type.
`typinput`	regproc	pg_proc.oid	Input conversion function (text format)
`typoutput`	regproc	pg_proc.oid	Output conversion function (text format)
`typreceive`	regproc	pg_proc.oid	Input conversion function (binary format), or 0 if none
`typsend`	regproc	pg_proc.oid	Output conversion function (binary format), or 0 if none
`typmodin`	regproc	pg_proc.oid	Type modifier input function, or 0 if the type does not support modifiers
`typmodout`	regproc	pg_proc.oid	Type modifier output function, or 0 to use the standard format
`typanalyze`	regproc	pg_proc.oid	Custom `ANALYZE` function, or 0 to use the standard function
`typalign`	char		The alignment required when storing a value of this type. It applies to storage on disk as well as most representations of the value inside WarehousePG. When multiple values are stored consecutively, such as in the representation of a complete row on disk, padding is inserted before a datum of this type so that it begins on the specified boundary. The alignment reference is the beginning of the first datum in the sequence. Possible values are: `c` = char alignment (no alignment needed). `s` = short alignment (2 bytes on most machines). `i` = int alignment (4 bytes on most machines). `d` = double alignment (8 bytes on many machines, but not all).
`typstorage`	char		For varlena types (those with `typlen` = -1) tells if the type is prepared for toasting and what the default strategy for attributes of this type should be. Possible values are: `p`: Value must always be stored plain. `e`: Value can be stored in a secondary relation (if relation has one, see `pg_class.reltoastrelid`). `m`: Value can be stored compressed inline. `x`: Value can be stored compressed inline or stored in secondary storage. Note that `m` columns can also be moved out to secondary storage, but only as a last resort (`e` and `x` columns are moved first).
`typnotnull`	boolean		Represents a not-null constraint on a type. Used for domains only.

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column	type	references	description
`typbasetype`	oid	pg_type.oid	Identifies the type that a domain is based on. Zero if this type is not a domain.
`typtypmod`	integer		Domains use `typtypmod` to record the `typmod` to be applied to their base type (-1 if base type does not use a `typmod`). -1 if this type is not a domain.
`typndims`	integer		The number of array dimensions for a domain over an array (if `typbasetype` is an array type). Zero for types other than domains over array types.
`typcollation`	oid	pg_collation.oid	Specifies the collation of the type. Zero if the type does not support collations. The value is `DEFAULT_COLLATION_OID` for a base type that supports collations. A domain over a collatable type can have some other collation OID if one was specified for the domain.
`typdefaultbin`	pg_node_tree		If not null, it is the `nodeToString()` representation of a default expression for the type. This is only used for domains.
`typdefault`	text		Null if the type has no associated default value. If `typdefaultbin` is not null, `typdefault` must contain a human-readable version of the default expression represented by `typdefaultbin`. If `typdefaultbin` is null and `typdefault` is not, then `typdefault` is the external representation of the type's default value, which may be fed to the type's input converter to produce a constant.
`typacl`	aclitem[]		Access privileges; see GRANT and REVOKE for details.

The following table lists the system-defined values of `typcategory`. Any future additions to this list will also be upper-case ASCII letters. All other ASCII characters are reserved for user-defined categories.

Code	Category
A	Array types
B	Boolean types
C	Composite types
D	Date/time types
E	Enum types
G	Geometric types
I	Network address types
N	Numeric types
P	Pseudo-types
R	Range types
S	String types
T	Timespan types
U	User-defined types
V	Bit-string types
X	`unknown` type

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7.8.3.75 pg_type_encoding

The `pg_type_encoding` system catalog table contains the column storage type information.

column	type	modifers	storage	description
`typeid`	oid	not null	plain	Foreign key to pg_attribute
`typoptions`	text [ ]		extended	The actual options

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7.8.3.76 pg_user_mapping

The system catalog table `pg_user_mapping` stores the mappings from local user to remote user. You must have administrator privileges to view this catalog. Access to this catalog is restricted from normal users, use the `pg_user_mappings` view instead.

column	type	references	description
`oid`	oid		The object ID
`umuser`	oid	pg_authid.oid	OID of the local role being mapped, 0 if the user mapping is public.
`umserver`	oid	pg_foreign_server.oid	OID of the foreign server that contains this mapping
`umoptions`	text[]		User mapping-specific options, as "keyword=value" strings.

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7.8.3.77 pg_user_mappings

The `pg_user_mappings` view provides access to information about user mappings. This view is essentially a public-readble view of the `pg_user_mapping` system catalog table that omits the options field if the user does not have access rights to view it.

column	type	references	description
`umid`	oid	pg_user_mapping.oid	OID of the user mapping.
`srvid`	oid	pg_foreign_server.oid	OID of the foreign server that contains this mapping.
`srvname`	text	pg_foreign_server.srvname	Name of the foreign server.
`umuser`	oid	pg_authid.oid	OID of the local role being mapped, 0 if the user mapping is public.
`usename`	name		Name of the local user to be mapped.
`umoptions`	text[]		User mapping-specific options, as "keyword=value" strings.

To protect password information stored as a user mapping option, the `umoptions` column reads as null unless one of the following applies:

- The current user is the user being mapped, and owns the server or holds `USAGE` privilege on it.
- The current user is the server owner and the mapping is for `PUBLIC`.
- The current user is a superuser.

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7.8.3.78 user_mapping_options

The `user_mapping_options` view contains all of the options defined for user mappings in the current database. WarehousePG displays only those user mappings to which the current user has access (by way of being the owner or having some privilege).

column	type	references	description
`authorization_identifier`	sql_identifier		Name of the user being mapped, or `PUBLIC` if the mapping is public.
`foreign_server_catalog`	sql_identifier		Name of the database in which the foreign server used by this mapping is defined (always the current database).
`foreign_server_name`	sql_identifier		Name of the foreign server used by this mapping.
`option_name`	sql_identifier		Name of an option.
`option_value`	character_data		Value of the option. This column will display null unless: - The current user is the user being mapped. - The mapping is for `PUBLIC` and the current user is the foreign server owner. - The current user is a superuser. The intent is to protect password information stored as a user mapping option.

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7.8.3.79 user_mappings

The `user_mappings` view contains all of the user mappings defined in the current database. WarehousePG displays only those user mappings to which the current user has access (by way of being the owner or having some privilege).

column	type	references	description
`authorization_identifier`	sql_identifier		Name of the user being mapped, or `PUBLIC` if the mapping is public.
`foreign_server_catalog`	sql_identifier		Name of the database in which the foreign server used by this mapping is defined (always the current database).
`foreign_server_name`	sql_identifier		Name of the foreign server used by this mapping.

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7.8.3.80 pg_sequence

The system catalog table `pg_sequence` contains information about sequences. Some information about sequences, such as the name and the schema, is stored in the`pg_class` system table.

column	type	references	description
`seqrelid`	oid	`pg_class.oid`	OID of the `pg_class` entry for this sequence
`seqtypid`	oid	`pg_type.oid`	Data type of the sequence
`seqstart`	bigint		Start value of the sequence
`seqincrement`	bigint		Increment value of the sequence
`seqmax`	bigint		Maximum value of the sequence
`seqmin`	bigint		Minimum value of the sequence
`seqcache`	bigint		Cache size of the sequence
`seqcycle`	boolean		Whether the sequence cycles

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7.8.4 System Catalog Functions

WarehousePG provides the following system catalog functions:

> **Note** This list is provisional and may be incomplete.

- gp_get_suboverflowed_backends
- pg_stat_get_backend_subxact

Statistics Functions

The following functions support collection and reporting of information about server activity.

gp_get_suboverflowed_backends

`gp_get_suboverflowed_backends()` return type is `integer[]`.

Returns an array of integers which indicate the process IDs of all the sessions in which a backend has subtransaction overflows on the running segment. For a cluster-wide view of the suboverflowed backends on every segment, use the view gp_suboverflowed_backend.

pg_stat_get_backend_subxacts

`pg_stat_get_backend_subxact(integer)` return type is `record`.

Returns a record of information about the subtransactions of the backend with the specified ID. The fields returned are `subxact_count`, which is the number of subtransactions in the backend's subtransaction cache, and `subxact_overflow`, which indicates whether the backend's subtransaction cache is overflowed or not.

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7.9 The gp_toolkit Administrative Schema

WarehousePG provides an administrative schema called `gp_toolkit` that you can use to query the system catalogs, log files, and operating environment for system status information. The `gp_toolkit` schema contains a number of views that you can access using SQL commands. The `gp_toolkit` schema is accessible to all database users, although some objects may require superuser permissions. For convenience, you may want to add the `gp_toolkit` schema to your schema search path. For example:

```
=> ALTER ROLE myrole SET search_path TO myschema,gp_toolkit;
```

This documentation describes the most useful views and user-defined functions (UDFs) in `gp_toolkit`. You may notice other objects (views, functions, and external tables) within the `gp_toolkit` schema that are not described in this documentation (these are supporting objects to the views described in this section).

> **Caution** Do not change database objects in the gp_toolkit schema. Do not create database objects in the schema. Changes to objects in the schema might affect the accuracy of administrative information returned by schema objects. Any changes made in the gp_toolkit schema are lost when the database is backed up and then restored with the `gpbackup` and `gprestore` utilities.

These are the categories for views in the `gp_toolkit` schema.

- Checking for Tables that Need Routine Maintenance
- Checking for Locks
- Checking Append-Optimized Tables
- Viewing WarehousePG Server Log Files
- Checking Server Configuration Files
- Checking for Failed Segments
- Checking Resource Group Activity and Status
- Checking Resource Queue Activity and Status
- Checking Query Disk Spill Space Usage
- Viewing Users and Groups (Roles)
- Checking Database Object Sizes and Disk Space
- Checking for Missing and Orphaned Data Files
- Moving Orphaned Data Files
- Checking for Uneven Data Distribution
- Maintaining Partitions

About the Extension

`gp_toolkit` is implemented as an extension in WarehousePG 7. Because this extension is registered in the `template1` database, it is both registered an immediately available to use in every WarehousePG that you create.

Upgrading the Extension

The `gp_toolkit` extension is installed when you install or upgrade WarehousePG. A previous version of the extension will continue to work in existing databases after you upgrade WarehousePG. To upgrade to the most recent version of the extension, you must:

```
ALTER EXTENSION gp_toolkit UPDATE TO '1.4';
```

in **every** database in which you use the extension.

Checking for Tables that Need Routine Maintenance

The following views can help identify tables that need routine table maintenance (`VACUUM` and/or `ANALYZE`).

- gp_bloat_diag
- gp_stats_missing

The `VACUUM` or `VACUUM FULL` command reclaims disk space occupied by deleted or obsolete rows. Because of the MVCC transaction concurrency model used in WarehousePG, data rows that are deleted or updated still occupy physical space on disk even though they are not visible to any new transactions. Expired rows increase table size on disk and eventually slow down scans of the table.

The `ANALYZE` command collects column-level statistics needed by the query optimizer. WarehousePG uses a cost-based query optimizer that relies on database statistics. Accurate statistics allow the query optimizer to better estimate selectivity and the number of rows retrieved by a query operation in order to choose the most efficient query plan.

Parent topic: The gp_toolkit Administrative Schema

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gp_bloat_diag

This view shows regular heap-storage tables that have bloat (the actual number of pages on disk exceeds the expected number of pages given the table statistics). Tables that are bloated require a `VACUUM` or a `VACUUM FULL` in order to reclaim disk space occupied by deleted or obsolete rows. This view is accessible to all users, however non-superusers will only be able to see the tables that they have permission to access.

> **Note** For diagnostic functions that return append-optimized table information, see Checking Append-Optimized Tables.

Column	Description
bdirelid	Table object id.
bdinspname	Schema name.
bdirelname	Table name.
bdirelpages	Actual number of pages on disk.
bdiexppages	Expected number of pages given the table data.
bdidiag	Bloat diagnostic message.

gp_stats_missing

This view shows tables that do not have statistics and therefore may require an `ANALYZE` be run on the table.

Column	Description
smischema	Schema name.
smitable	Table name.
smisize	Does this table have statistics? False if the table does not have row count and row sizing statistics recorded in the system catalog, which may indicate that the table needs to be analyzed. This will also be false if the table does not contain any rows. For example, the parent tables of partitioned tables are always empty and will always return a false result.
smicols	Number of columns in the table.
smirecs	The total number of columns in the table that have statistics recorded.

Checking for Locks

When a transaction accesses a relation (such as a table), it acquires a lock. Depending on the type of lock acquired, subsequent transactions may have to wait before they can access the same relation. For more information on the types of locks, see the Managing Datatopic. WarehousePG resource queues (used for resource management) also use locks to control the admission of queries into the system.

The `gp_locks_*` family of views can help diagnose queries and sessions that are waiting to access an object due to a lock.

- gp_locks_on_relation
- gp_locks_on_resqueue

Parent topic: The gp_toolkit Administrative Schema

gp_locks_on_relation

This view shows any locks currently being held on a relation, and the associated session information about the query associated with the lock. For more information on the types of locks, see theManaging Data topic. This view is accessible to all users, however non-superusers will only be able to see the locks for relations that they have permission to access.

Column	Description
lorlocktype	Type of the lockable object: `relation`, `extend`, `page`, `tuple`, `transactionid`, `object`, `userlock`, `resource queue`, or `advisory`
lordatabase	Object ID of the database in which the object exists, zero if the object is a shared object.
lorrelname	The name of the relation.
lorrelation	The object ID of the relation.
lortransaction	The transaction ID that is affected by the lock.
lorpid	Process ID of the server process holding or awaiting this lock. NULL if the lock is held by a prepared transaction.
lormode	Name of the lock mode held or desired by this process.
lorgranted	Displays whether the lock is granted (true) or not granted (false).
lorcurrentquery	The current query in the session.

gp_locks_on_resqueue

> **Note** The `gp_locks_on_resqueue` view is valid only when resource queue-based resource management is active.

This view shows any locks currently being held on a resource queue, and the associated session information about the query associated with the lock. This view is accessible to all users, however non-superusers will only be able to see the locks associated with their own sessions.

Column	Description
lorusename	Name of the user running the session.
lorrsqname	The resource queue name.
lorlocktype	Type of the lockable object: `resource queue`
lorobjid	The ID of the locked transaction.
lortransaction	The ID of the transaction that is affected by the lock.
lorpid	The process ID of the transaction that is affected by the lock.
lormode	The name of the lock mode held or desired by this process.

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Column	Description
lorgranted	Displays whether the lock is granted (true) or not granted (false).
lorwaiting	Displays whether or not the session is waiting.

Checking Append-Optimized Tables

The `gp_toolkit` schema includes a set of diagnostic functions you can use to investigate the state of append-optimized tables.

When an append-optimized table (or column-oriented append-optimized table) is created, another table is implicitly created, containing metadata about the current state of the table. The metadata includes information such as the number of records in each of the table's segments.

Append-optimized tables may have non-visible rows—rows that have been updated or deleted, but remain in storage until the table is compacted using `VACUUM`. The hidden rows are tracked using an auxiliary visibility map table, or visimap.

The following functions let you access the metadata for append-optimized and column-oriented tables and view non-visible rows.

For most of the functions, the input argument is `regclass`, either the table `name` or the `oid` of a table.

Parent topic: The gp_toolkit Administrative Schema

__gp_aovisimap_compaction_info(oid)

This function displays compaction information for an append-optimized table. The information is for the on-disk data files on database segments that store the table data. You can use the information to determine the data files that will be compacted by a `VACUUM` operation on an append-optimized table.

> **Note** Until a VACUUM operation deletes the row from the data file, deleted or updated data rows occupy physical space on disk even though they are hidden to new transactions. The configuration parameter gp_appendonly_compaction controls the functionality of the `VACUUM` command.

This table describes the __gp_aovisimap_compaction_info function output table.

Column	Description
content	Database segment ID.
datafile	ID of the data file on the segment.
compaction_possible	The value is either `t` or `f`. The value `t` indicates that the data in data file be compacted when a VACUUM operation is performed. The server configuration parameter `gp_appendonly_compaction_threshold` affects this value.
hidden_tupcount	In the data file, the number of hidden (deleted or updated) rows.
total_tupcount	In the data file, the total number of rows.
percent_hidden	In the data file, the ratio (as a percentage) of hidden (deleted or updated) rows to total rows.

__gp_aoseg(regclass)

This function returns metadata information contained in the append-optimized table's on-disk segment file.

The input argument is the name or the oid of an append-optimized table.

Column	Description
segno	The file segment number.
eof	The effective end of file for this file segment.
tupcount	The total number of tuples in the segment, including invisible tuples.
varblockcount	The total number of varblocks in the file segment.
eof_uncompressed	The end of file if the file segment were uncompressed.
modcount	The number of data modification operations.
state	The state of the file segment. Indicates if the segment is active or ready to be dropped after compaction.

__gp_aoseg_history(regclass)

This function returns metadata information contained in the append-optimized table's on-disk segment file. It displays all different versions (heap tuples) of the aoseg meta information. The data is complex, but users with a deep understanding of the system may find it useful for debugging.

The input argument is the name or the oid of an append-optimized table.

Column	Description
gp_tid	The id of the tuple.
gp_xmin	The id of the earliest transaction.
gp_xmin_status	Status of the gp_xmin transaction.
gp_xmin_commit_	The commit distribution id of the gp_xmin transaction.
gp_xmax	The id of the latest transaction.
gp_xmax_status	The status of the latest transaction.
gp_xmax_commit_	The commit distribution id of the gp_xmax transaction.
gp_command_id	The id of the query command.

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Column	Description
gp_infomask	A bitmap containing state information.
gp_update_tid	The ID of the newer tuple if the row is updated.
gp_visibility	The tuple visibility status.
segno	The number of the segment in the segment file.
tupcount	The number of tuples, including hidden tuples.
eof	The effective end of file for the segment.
eof_uncompressed	The end of file for the segment if data were uncompressed.
modcount	A count of data modifications.
state	The status of the segment.

__gp_aocsseg(regclass)

This function returns metadata information contained in a column-oriented append-optimized table's on-disk segment file, excluding non-visible rows. Each row describes a segment for a column in the table.

The input argument is the name or the oid of a column-oriented append-optimized table.

Column	Description
gp_tid	The table id.
segno	The segment number.
column_num	The column number.
physical_segno	The number of the segment in the segment file.
tupcount	The number of rows in the segment, excluding hidden tuples.
eof	The effective end of file for the segment.
eof_uncompressed	The end of file for the segment if the data were uncompressed.
modcount	A count of data modification operations for the segment.
state	The status of the segment.

__gp_aocsseg_history(regclass)

This function returns metadata information contained in a column-oriented append-optimized table's on-disk segment file. Each row describes a segment for a column in the table. The data is complex, but users with a deep understanding of the system may find it useful for debugging.

The input argument is the name or the oid of a column-oriented append-optimized table.

Column	Description
gp_tid	The oid of the tuple.
gp_xmin	The earliest transaction.
gp_xmin_status	The status of the gp_xmin transaction.
gp_xmin_	Text representation of gp_xmin.
gp_xmax	The latest transaction.
gp_xmax_status	The status of the gp_xmax transaction.
gp_xmax_	Text representation of gp_max.
gp_command_id	ID of the command operating on the tuple.
gp_infomask	A bitmap containing state information.
gp_update_tid	The ID of the newer tuple if the row is updated.
gp_visibility	The tuple visibility status.
segno	The segment number in the segment file.
column_num	The column number.
physical_segno	The segment containing data for the column.
tupcount	The total number of tuples in the segment.
eof	The effective end of file for the segment.
eof_uncompressed	The end of file for the segment if the data were uncompressed.
modcount	A count of the data modification operations.
state	The state of the segment.

__gp_aovisimap(regclass)

This function returns the tuple ID, the segment file, and the row number of each non-visible tuple according to the visibility map.

The input argument is the name or the oid of an append-optimized table.

Column	Description
tid	The tuple id.
segno	The number of the segment file.
row_num	The row number of a row that has been deleted or updated.

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__gp_aovisimap_hidden_info(regclass)

This function returns the numbers of hidden and visible tuples in the segment files for an append-optimized table.

The input argument is the name or the oid of an append-optimized table.

Column	Description
segno	The number of the segment file.
hidden_tupcount	The number of hidden tuples in the segment file.
total_tupcount	The total number of tuples in the segment file.

__gp_aovisimap_entry(regclass)

This function returns information about each visibility map entry for the table.

The input argument is the name or the oid of an append-optimized table.

Column	Description
segno	Segment number of the visibility map entry.
first_row_num	The first row number of the entry.
hidden_tupcount	The number of hidden tuples in the entry.
bitmap	A text representation of the visibility bitmap.

__gp_aoblkdir(regclass)

For a given AO/AOCO table that had or has an index, this function returns a row for each block directory entry recorded in the block directory relation; it flattens the `minipage` column of block directory relations and returns a row for each `minipage` entry.

The input argument is the name or the oid of an append-optimized table.

You must execute this function in utility mode against every segment, or with `gp_dist_random()` as shown here:

```
SELECT
(gp_toolkit.__gp_aoblkdir('<table_name>')).*
    FROM gp_dist_random('gp_id');
```

Column	Description
tupleid	The tuple id of the block directory row containing this block directory entry.
segno	The physical segment file number.
columngroup_no	The `attnum` of the column described by this `minipage` entry (always `0` for row-oriented tables).
entry_no	The entry serial number inside this `minipage` containing this block directory entry.
first_row_no	The first row number of the rows covered by this block directory entry.
file_offset	The starting file offset of the rows covered by this block directory entry.
row_count	The count of rows covered by this block directory entry.

get_column_size(oid)

For a given AOCO table, this function returns the column size and compression ratio for all columns in the table.

The input argument is the object identifier of a column-oriented append-optimized table.

Column	Description
segment	The segment id.
attnum	The attribute number of the column.
size	The size of the column in bytes.
size_uncompressed	The size of the column in bytes if the column was not compressed.
compression_ratio	The compression ratio.

gp_column_size

This view gathers the column size and compression ratio for column-oriented append-optimized tables from all segments.

Column	Description
relname	The table name.
segment	The segment id.
attnum	The attribute number of the column.
attname	The column name.
size	The size of the column in bytes.

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Column	Description
size_uncompressed	The size of the column in bytes if the column was not compressed.
compression_ratio	The compression ratio.

gp_column_size_summary

This view shows a summary of the `gp_column_size` view. It aggregates the column size and compression ratio for each column in each column-oriented append-optimized table from all segments.

Column	Description
relname	The table name.
attnum	The attribute number of the column.
size	The size of the column in bytes.
size_uncompressed	The size of the column in bytes if the column were uncompressed.
compression_ratio	The compression ratio.

Viewing WarehousePG Server Log Files

Each component of a WarehousePG cluster (coordinator, standby coordinator, primary segments, and mirror segments) keeps its own server log files. The `gp_log_*` family of views allows you to issue SQL queries against the server log files to find particular entries of interest. The use of these views require superuser permissions.

- gp_log_command_timings
- gp_log_database
- gp_log_coordinator_concise
- gp_log_system

Parent topic: The gp_toolkit Administrative Schema

gp_log_command_timings

This view uses an external table to read the log files on the coordinator and report the run time of SQL commands in a database session. The use of this view requires superuser permissions.

Column	Description
logsession	The session identifier (prefixed with "con").
logcmdcount	The command number within a session (prefixed with "cmd").
logdatabase	The name of the database.
loguser	The name of the database user.
logpid	The process id (prefixed with "p").
logtimemin	The time of the first log message for this command.
logtimemax	The time of the last log message for this command.
logduration	Statement duration from start to end time.

gp_log_database

This view uses an external table to read the server log files of the entire WarehousePG cluster (coordinator, segments, and mirrors) and lists log entries associated with the current database. Associated log entries can be identified by the session id (logsession) and command id (logcmdcount). The use of this view requires superuser permissions.

Column	Description
logtime	The timestamp of the log message.
loguser	The name of the database user.
logdatabase	The name of the database.
logpid	The associated process id (prefixed with "p").
logthread	The associated thread count (prefixed with "th").
loghost	The segment or coordinator host name.
logport	The segment or coordinator port.
logsessiontime	Time session connection was opened.
logtransaction	Global transaction id.
logsession	The session identifier (prefixed with "con").
logcmdcount	The command number within a session (prefixed with "cmd").
logsegment	The segment content identifier (prefixed with "seg" for primary or "mir" for mirror. The coordinator always has a content id of -1).
logslice	The slice id (portion of the query plan being run).
logdistxact	Distributed transaction id.
loglocalxact	Local transaction id.
logsubxact	Subtransaction id.
logseverity	LOG, ERROR, FATAL, PANIC, DEBUG1 or DEBUG2.
logstate	SQL state code associated with the log message.
logmessage	Log or error message text.
logdetail	Detail message text associated with an error message.

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Column	Description
loghint	Hint message text associated with an error message.
logquery	The internally-generated query text.
logquerypos	The cursor index into the internally-generated query text.
logcontext	The context in which this message gets generated.
logdebug	Query string with full detail for debugging.
logcursorpos	The cursor index into the query string.
logfunction	The function in which this message is generated.
logfile	The log file in which this message is generated.
logline	The line in the log file in which this message is generated.
logstack	Full text of the stack trace associated with this message.

gp_log_coordinator_concise

This view uses an external table to read a subset of the log fields from the coordinator log file. The use of this view requires superuser permissions.

Column	Description
logtime	The timestamp of the log message.
logdatabase	The name of the database.
logsession	The session identifier (prefixed with "con").
logcmdcount	The command number within a session (prefixed with "cmd").
logseverity	The log severity level.
logmessage	Log or error message text.

gp_log_system

This view uses an external table to read the server log files of the entire WarehousePG cluster (coordinator, segments, and mirrors) and lists all log entries. Associated log entries can be identified by the session id (logsession) and command id (logcmdcount). The use of this view requires superuser permissions.

Column	Description
logtime	The timestamp of the log message.
loguser	The name of the database user.
logdatabase	The name of the database.
logpid	The associated process id (prefixed with "p").
logthread	The associated thread count (prefixed with "th").
loghost	The segment or coordinator host name.
logport	The segment or coordinator port.
logsessiontime	Time session connection was opened.
logtransaction	Global transaction id.
logsession	The session identifier (prefixed with "con").
logcmdcount	The command number within a session (prefixed with "cmd").
logsegment	The segment content identifier (prefixed with "seg" for primary or "mir" for mirror. The coordinator always has a content id of -1).
logslice	The slice id (portion of the query plan being run).
logdistxact	Distributed transaction id.
loglocalxact	Local transaction id.
logsubxact	Subtransaction id.
logseverity	LOG, ERROR, FATAL, PANIC, DEBUG1 or DEBUG2.
logstate	SQL state code associated with the log message.
logmessage	Log or error message text.
logdetail	Detail message text associated with an error message.
loghint	Hint message text associated with an error message.
logquery	The internally-generated query text.
logquerypos	The cursor index into the internally-generated query text.
logcontext	The context in which this message gets generated.
logdebug	Query string with full detail for debugging.
logcursorpos	The cursor index into the query string.
logfunction	The function in which this message is generated.
logfile	The log file in which this message is generated.
logline	The line in the log file in which this message is generated.
logstack	Full text of the stack trace associated with this message.

Checking Server Configuration Files

Each component of a WarehousePG cluster (coordinator, standby coordinator, primary segments, and mirror segments) has its own server configuration file (`postgresql.conf`). The following `gp_toolkit` objects can be used to check parameter settings across all primary `postgresql.conf` files in the system:

- gp_param_setting('parameter_name')
- gp_param_settings_seg_value_diffs

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Parent topic: The gp_toolkit Administrative Schema

gp_param_setting('parameter_name')

This function takes the name of a server configuration parameter and returns the `postgresql.conf` value for the coordinator and each active segment. This function is accessible to all users.

Column	Description
paramsegment	The segment content id (only active segments are shown). The coordinator content id is always -1.
paramname	The name of the parameter.
paramvalue	The value of the parameter.

Example:

```
SELECT * FROM gp_param_setting('max_connections');
```

gp_param_settings_seg_value_diffs

Server configuration parameters that are classified as *local* parameters (meaning each segment gets the parameter value from its own `postgresql.conf` file), should be set identically on all segments. This view shows local parameter settings that are inconsistent. Parameters that are supposed to have different values (such as `port`) are not included. This view is accessible to all users.

Column	Description
psdname	The name of the parameter.
psdvalue	The value of the parameter.
psdcount	The number of segments that have this value.

Checking for Failed Segments

The gp_pgdatabase_invalid view can be used to check for down segments.

Parent topic: The gp_toolkit Administrative Schema

gp_pgdatabase_invalid

This view shows information about segments that are marked as down in the system catalog. This view is accessible to all users.

Column	Description
pgdbidbid	The segment dbid. Every segment has a unique dbid.
pgdbiisprimary	Is the segment currently acting as the primary (active) segment? (t or f)
pgdbicontent	The content id of this segment. A primary and mirror will have the same content id.
pgdbivalid	Is this segment up and valid? (t or f)
pgdbidefinedprimary	Was this segment assigned the role of primary at system initialization time? (t or f)

Checking Resource Group Activity and Status

> **Note** The resource group activity and status views described in this section are valid only when resource group-based resource management is active.

Resource groups manage transactions to avoid exhausting system CPU and memory resources. Every database user is assigned a resource group. WarehousePG evaluates every transaction submitted by a user against the limits configured for the user's resource group before running the transaction.

You can use the `gp_resgroup_config` view to check the configuration of each resource group. You can use the `gp_resgroup_status*` views to display the current transaction status and resource usage of each resource group.

- gp_resgroup_config
- gp_resgroup_role
- gp_resgroup_status
- gp_resgroup_status_per_host

Parent topic: The gp_toolkit Administrative Schema

gp_resgroup_config

The `gp_resgroup_config` view allows administrators to see the current CPU, memory, and concurrency limits for a resource group.

This view is accessible to all users.

Column	Description
groupid	The ID of the resource group.
groupname	The name of the resource group.

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Column	Description
concurrency	The concurrency (`CONCURRENCY`) value specified for the resource group.
cpu_max_percent	The CPU limit (`CPU_MAX_PERCENT`) value specified for the resource group, or `-1`.
cpu_weight	The scheduling priority of the resource group (CPU_WEIGHT).
cpuset	The CPU cores reserved for the resource group (CPUSET), or `-1`.
memory_quota	The memory quota (`MEMORY_QUOTA`) value specified for the resource group.
min_cost	The minimum cost of a query plan to be included in the resource group (MIN_COST).
io_limit	The maximum read/write sequential disk I/O throughput, and the maximum read/write I/O operations per second for the queries assigned to a specific tablespace (shown as the tablespace oid) and resource group (IO_LIMIT).

gp_resgroup_role

The `gp_resgroup_role` view allows administrators to see the resource group assigned to every role.

This view is accessible to all users.

Column	Description
rrrolname	The name of the role
rrrsgname	The name of the resource group

gp_resgroup_status

The `gp_resgroup_status` view allows administrators to see status and activity for a resource group. It shows how many queries are waiting to run and how many queries are currently active in the system for each resource group. The view also displays current memory and CPU usage for the resource group.

> **Note** Resource groups use the Linux control groups (cgroups) configured on the host systems. The cgroups are used to manage host system resources. When resource groups use cgroups that are as part of a nested set of cgroups, resource group limits are relative to the parent cgroup allotment. For information about nested cgroups and WarehousePG resource group limits, see Using Resource Groups.

This view is accessible to all users.

Column	Description
rsgname	The name of the resource group.
groupid	The ID of the resource group.
num_running	The number of transactions currently running in the resource group.
num_queueing	The number of currently queued transactions for the resource group.
num_queued	The total number of queued transactions for the resource group since the WarehousePG cluster was last started, excluding the num_queueing.
num_executed	The total number of transactions run in the resource group since the WarehousePG cluster was last started, excluding the num_running.
total_queue_duration	The total time any transaction was queued since the WarehousePG cluster was last started.

Sample output for the `gp_resgroup_status` view:

```
select * from gp_toolkit.gp_resgroup_status;
 rsgname       | groupid | num_running | num_queueing | num_queued | num_executed | total_queue_duration |
---------------+---------+-------------+--------------+------------+--------------------------------------------------------------------------
 default_group | 6437    | 0           | 0            | 0          | 0            | @ 0                  |
 admin_group   | 6438    | 1           | 0            | 0          | 13           | @ 0                  |
 system_group  | 6441    | 0           | 0            | 0          | 0            | @ 0                  |
(3 rows)
```

gp_resgroup_status_per_host

The gp_resgroup_status_per_host view displays the real-time CPU and memory usage (MBs) for each resource group on a per-host basis. The view also displays available and granted group fixed and shared memory for each resource group on a host.

Column	Description
`rsgname`	The name of the resource group.
`groupid`	The ID of the resource group.
`hostname`	The hostname of the segment host.
`cpu_usage`	The real-time CPU core usage by the resource group on a host. The value is the sum of the percentages (as a float value) of the CPU cores that are used by the resource group on the host.
`memory_usage`	The real-time memory usage of the resource group on each database segment's host, in MB.

Sample output for the `gp_resgroup_status_per_host` view:

```
select * from gp_toolkit.gp_resgroup_status_per_host;
 rsgname       | groupid | hostname | cpu_usage | memory_usage
---------------+---------+----------+-----------+--------------
 admin_group   | 6438    | zero     | 0.07      | 91.92
 default_group | 6437    | zero     | 0.00      | 0.00
 system_group  | 6441    | zero     | 0.02      | 53.04
(3 rows)
```

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Checking Resource Queue Activity and Status

> **Note** The resource queue activity and status views described in this section are valid only when resource queue-based resource management is active.

The purpose of resource queues is to limit the number of active queries in the system at any given time in order to avoid exhausting system resources such as memory, CPU, and disk I/O. All database users are assigned to a resource queue, and every statement submitted by a user is first evaluated against the resource queue limits before it can run. The `gp_resq_*` family of views can be used to check the status of statements currently submitted to the system through their respective resource queue. Note that statements issued by superusers are exempt from resource queuing.

- gp_resq_activity
- gp_resq_activity_by_queue
- gp_resq_priority_statement
- gp_resq_role
- gp_resqueue_status

Parent topic: The gp_toolkit Administrative Schema

gp_resq_activity

For the resource queues that have active workload, this view shows one row for each active statement submitted through a resource queue. This view is accessible to all users.

Column	Description
resqprocpid	Process ID assigned to this statement (on the coordinator).
resqrole	User name.
resqoid	Resource queue object id.
resqname	Resource queue name.
resqstart	Time statement was issued to the system.
resqstatus	Status of statement: running, waiting or cancelled.

gp_resq_activity_by_queue

For the resource queues that have active workload, this view shows a summary of queue activity. This view is accessible to all users.

Column	Description
resqoid	Resource queue object id.
resqname	Resource queue name.
resqlast	Time of the last statement issued to the queue.
resqstatus	Status of last statement: running, waiting or cancelled.
resqtotal	Total statements in this queue.

gp_resq_priority_statement

This view shows the resource queue priority, session ID, and other information for all statements currently running in the WarehousePG cluster. This view is accessible to all users.

Column	Description
rqpdatname	The database name that the session is connected to.
rqpusename	The user who issued the statement.
rqpsession	The session ID.
rqpcommand	The number of the statement within this session (the command id and session id uniquely identify a statement).
rqppriority	The resource queue priority for this statement (MAX, HIGH, MEDIUM, LOW).
rqpweight	An integer value associated with the priority of this statement.
rqpquery	The query text of the statement.

gp_resq_role

This view shows the resource queues associated with a role. This view is accessible to all users.

Column	Description
rrrolname	Role (user) name.
rrrsqname	The resource queue name assigned to this role. If a role has not been explicitly assigned to a resource queue, it will be in the default resource queue (*pg_default*).

gp_resqueue_status

This view allows administrators to see status and activity for a resource queue. It shows how many queries are waiting to run and how many queries are currently active in the system from a particular resource queue.

Column	Description
`queueid`	The ID of the resource queue.
`rsqname`	The name of the resource queue.
`rsqcountlimit`	The active query threshold of the resource queue. A value of -1 means no limit.
`rsqcountvalue`	The number of active query slots currently being used in the resource queue.

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Column	Description
rsqcostlimit	The query cost threshold of the resource queue. A value of -1 means no limit.
rsqcostvalue	The total cost of all statements currently in the resource queue.
rsqmemorylimit	The memory limit for the resource queue.
rsqmemoryvalue	The total memory used by all statements currently in the resource queue.
rsqwaiters	The number of statements currently waiting in the resource queue.
rsqholders	The number of statements currently running on the system from this resource queue.

Checking Query Disk Spill Space Usage

The *gp_workfile_** views show information about all the queries that are currently using disk spill space. WarehousePG creates work files on disk if it does not have sufficient memory to run the query in memory. This information can be used for troubleshooting and tuning queries. The information in the views can also be used to specify the values for the WarehousePG configuration parameters `gp_workfile_limit_per_query` and `gp_workfile_limit_per_segment`.

- gp_workfile_entries
- gp_workfile_usage_per_query
- gp_workfile_usage_per_segment

Parent topic: The gp_toolkit Administrative Schema

gp_workfile_entries

This view contains one row for each operator using disk space for workfiles on a segment at the current time. The view is accessible to all users, however non-superusers only to see information for the databases that they have permission to access.

Column	Type	References	Description
datname	name		Database name.
pid	integer		Process ID of the server process.
sess_id	integer		Session ID.
command_cnt	integer		Command ID of the query.
usename	name		Role name.
query	text		Current query that the process is running.
segid	integer		Segment ID.
slice	integer		The query plan slice. The portion of the query plan that is being run.
optype	text		The query operator type that created the work file.
size	bigint		The size of the work file in bytes.
numfiles	integer		The number of files created.
prefix	text		Prefix used when naming a related set of workfiles.

gp_workfile_usage_per_query

This view contains one row for each query using disk space for workfiles on a segment at the current time. The view is accessible to all users, however non-superusers only to see information for the databases that they have permission to access.

Column	Type	References	Description
datname	name		Database name.
pid	integer		Process ID of the server process.
sess_id	integer		Session ID.
command_cnt	integer		Command ID of the query.
usename	name		Role name.
query	text		Current query that the process is running.
segid	integer		Segment ID.
size	numeric		The size of the work file in bytes.
numfiles	bigint		The number of files created.

gp_workfile_usage_per_segment

This view contains one row for each segment. Each row displays the total amount of disk space used for workfiles on the segment at the current time. The view is accessible to all users, however non-superusers only to see information for the databases that they have permission to access.

Column	Type	References	Description
segid	smallint		Segment ID.
size	numeric		The total size of the work files on a segment.
numfiles	bigint		The number of files created.

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Viewing Users and Groups (Roles)

It is frequently convenient to group users (roles) together to ease management of object privileges: that way, privileges can be granted to, or revoked from, a group as a whole. In WarehousePG, this is done by creating a role that represents the group, and then granting membership in the group role to individual user roles.

The gp_roles_assigned view can be used to see all of the roles in the system, and their assigned members (if the role is also a group role).

Parent topic: The gp_toolkit Administrative Schema

gp_roles_assigned

This view shows all of the roles in the system, and their assigned members (if the role is also a group role). This view is accessible to all users.

Column	Description
raroleid	The role object ID. If this role has members (users), it is considered a *group* role.
rarolename	The role (user or group) name.
ramemberid	The role object ID of the role that is a member of this role.
ramembername	Name of the role that is a member of this role.

Checking Database Object Sizes and Disk Space

The `gp_size_*` family of views can be used to determine the disk space usage for a distributed WarehousePG, schema, table, or index. The following views calculate the total size of an object across all primary segments (mirrors are not included in the size calculations).

- gp_size_of_all_table_indexes
- gp_size_of_database
- gp_size_of_index
- gp_size_of_schema_disk
- gp_size_of_table_and_indexes_disk
- gp_size_of_table_and_indexes_licensing
- gp_size_of_table_disk
- gp_size_of_table_uncompressed
- gp_disk_free

The table and index sizing views list the relation by object ID (not by name). To check the size of a table or index by name, you must look up the relation name (`relname`) in the `pg_class` table. For example:

```
SELECT relname as name, sotdsize as size, sotdtoastsize as
toast, sotdadditionalsize as other
FROM gp_size_of_table_disk as sotd, pg_class
WHERE sotd.sotdoid=pg_class.oid ORDER BY relname;
```

Parent topic: The gp_toolkit Administrative Schema

gp_size_of_all_table_indexes

This view shows the total size of all indexes for a table. This view is accessible to all users, however non-superusers will only be able to see relations that they have permission to access.

Column	Description
soatioid	The object ID of the table
soatisize	The total size of all table indexes in bytes
soatischemaname	The schema name
soatitablename	The table name

gp_size_of_database

This view shows the total size of a database. This view is accessible to all users, however non-superusers will only be able to see databases that they have permission to access.

Column	Description
sodddatname	The name of the database
sodddatsize	The size of the database in bytes

gp_size_of_index

This view shows the total size of an index. This view is accessible to all users, however non-superusers will only be able to see relations that they have permission to access.

Column	Description
soioid	The object ID of the index
soitableoid	The object ID of the table to which the index belongs
soisize	The size of the index in bytes
soiindexschemaname	The name of the index schema
soiindexname	The name of the index

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Column	Description
soitableschemaname	The name of the table schema
soitablename	The name of the table

gp_size_of_schema_disk

This view shows schema sizes for the public schema and the user-created schemas in the current database. This view is accessible to all users, however non-superusers will be able to see only the schemas that they have permission to access.

Column	Description
sosdnsp	The name of the schema
sosdschematablesize	The total size of tables in the schema in bytes
sosdschemaidxsize	The total size of indexes in the schema in bytes

gp_size_of_table_and_indexes_disk

This view shows the size on disk of tables and their indexes. This view is accessible to all users, however non-superusers will only be able to see relations that they have permission to access.

Column	Description
sotaidoid	The object ID of the parent table
sotaidtablesize	The disk size of the table
sotaididxsize	The total size of all indexes on the table
sotaidschemaname	The name of the schema
sotaidtablename	The name of the table

gp_size_of_table_and_indexes_licensing

This view shows the total size of tables and their indexes for licensing purposes. The use of this view requires superuser permissions.

Column	Description
sotailoid	The object ID of the table
sotailtablesizedisk	The total disk size of the table
sotailtablesizeuncompressed	If the table is a compressed append-optimized table, shows the uncompressed table size in bytes.
sotailindexessize	The total size of all indexes in the table
sotailschemaname	The schema name
sotailtablename	The table name

gp_size_of_table_disk

This view shows the size of a table on disk. This view is accessible to all users, however non-superusers will only be able to see tables that they have permission to access

Column	Description
sotdoid	The object ID of the table
sotdsize	The size of the table in bytes. The size is only the main table size. The size does not include auxiliary objects such as oversized (toast) attributes, or additional storage objects for AO tables.
sotdtoastsize	The size of the TOAST table (oversized attribute storage), if there is one.
sotdadditionalsize	Reflects the segment and block directory table sizes for append-optimized (AO) tables.
sotdschemaname	The schema name
sotdtablename	The table name

gp_size_of_table_uncompressed

This view shows the uncompressed table size for append-optimized (AO) tables. Otherwise, the table size on disk is shown. The use of this view requires superuser permissions.

Column	Description
sotuoid	The object ID of the table
sotusize	The uncomressed size of the table in bytes if it is a compressed AO table. Otherwise, the table size on disk.
sotuschemaname	The schema name
sotutablename	The table name

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gp_disk_free

This external table runs the `df` (disk free) command on the active segment hosts and reports back the results. Inactive mirrors are not included in the calculation. The use of this external table requires superuser permissions.

Column	Description
dfsegment	The content id of the segment (only active segments are shown)
dfhostname	The hostname of the segment host
dfdevice	The device name
dfspace	Free disk space in the segment file system in kilobytes

Checking for Missing and Orphaned Data Files

WarehousePG considers a relation data file that is present in the catalog, but not on disk, to be missing. Conversely, when WarehousePG encounters an unexpected data file on disk that is not referenced in any relation, it considers that file to be orphaned.

WarehousePG provides the following views to help identify if missing or orphaned files exist in the current database:

- gp_check_orphaned_files
- gp_check_missing_files
- gp_check_missing_files_ext

Consider it a best practice to check for these conditions prior to expanding the cluster or before offline maintenance.

By default, the views identified in this section are available to `PUBLIC`.

gp_check_orphaned_files

The `gp_check_orphaned_files` view scans the default and user-defined tablespaces for orphaned data files. WarehousePG considers normal data files, files with an underscore (`_`) in the name, and extended numbered files (files that contain a `.<N>` in the name) in this check. `gp_check_orphaned_files` gathers results from the WarehousePG coordinator and all segments.

Column	Description
gp_segment_id	The database segment identifier.
tablespace	The identifier of the tablespace in which the orphaned file resides.
filename	The file name of the orphaned data file.
filepath	The file system path of the orphaned data file, relative to the data directory of the coordinator or segment.

> **Caution** Use this view as one of many data points to identify orphaned data files. Do not delete files based solely on results from querying this view.

gp_check_missing_files

The `gp_check_missing_files` view scans heap and append-optimized, column-oriented tables for missing data files. WarehousePG considers only normal data files (files that do not contain a `.` or an `_` in the name) in this check. `gp_check_missing_files` gathers results from the WarehousePG coordinator and all segments.

Column	Description
gp_segment_id	The database segment identifier.
tablespace	The identifier of the tablespace in which the table resides.
relname	The name of the table that has a missing data file(s).
filename	The file name of the missing data file.

gp_check_missing_files_ext

The `gp_check_missing_files_ext` view scans only append-optimized, column-oriented tables for missing extended data files. WarehousePG considers both normal data files and extended numbered files (files that contain a `.<N>` in the name) in this check. Files that contain an `_` in the name are not considered. `gp_check_missing_files_ext` gathers results from the WarehousePG segments only.

Column	Description
gp_segment_id	The database segment identifier.
tablespace	The identifier of the tablespace in which the table resides.
relname	The name of the table that has a missing extended data file(s).
filename	The file name of the missing extended data file.

Moving Orphaned Data Files

The `gp_move_orphaned_files()` user-defined function (UDF) moves orphaned files found by thegp_check_orphaned_files view into a file system location that you specify.

The function signature is: `gp_move_orphaned_files( <target_directory> TEXT )`.

`<target_directory>` must exist on all segment hosts before you move the files, and the specified directory must be accessible by the `gpadmin` user. If you specify a relative path for `<target_directory>`, it is considered relative to the data directory of the coordinator or segment.

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WarehousePG renames each moved data file to one that reflects the original location of the file in the data directory. The file name format differs depending on the tablespace in which the orphaned file resides:

Tablespace	Renamed File Format
default	`seg<num>_base_<database-oid>_<relfilenode>`
global	`seg<num>_global_<relfilenode>`
user-defined	`seg<num>_pg_tblspc_<tablespace-oid>_<gpdb-version>_<database-oid>_<relfilenode>`

For example, if a file named `12345` in the default tablespace is orphaned on primary segment 2,

```
SELECT * FROM gp_move_orphaned_files('/home/gpadmin/orphaned');
```

moves and renames the file as follows:

Original Location	New Location and File Name
`<data_directory>/base/13700/12345`	`/home/gpadmin/orphaned/seg2_base_13700_12345`

`gp_move_orphaned_files()` returns both the original and the new file system locations for each file that it moves, and also provides an indication of the success or failure of the move operation. For example:

```
SELECT * FROM gp_toolkit.gp_move_orphaned_files('/home/gpadmin/orphaned');
 gp_segment_id | move_success |          oldpath          |         newpath
---------------+--------------+---------------------------+-----------------------------------
            -1 | t            | /<data_dir>/base/13715/99999 | /home/gpadmin/orphaned/seg-1_base_13715_99999
             1 | t            | /<data_dir>/base/13715/99999 | /home/gpadmin/orphaned/seg1_base_13715_99999
             2 | t            | /<data_dir>/base/13715/99999 | /home/gpadmin/orphaned/seg2_base_13715_99999
(3 rows)
```

Once you move the files, you may choose to remove them or to back them up.

Checking for Uneven Data Distribution

All tables in WarehousePG are distributed, meaning their data is divided across all of the segments in the system. If the data is not distributed evenly, then query processing performance may decrease. The following views can help diagnose if a table has uneven data distribution:

- gp_skew_coefficients
- gp_skew_idle_fractions

Parent topic: The gp_toolkit Administrative Schema

gp_skew_coefficients

This view shows data distribution skew by calculating the coefficient of variation (CV) for the data stored on each segment. This view is accessible to all users, however non-superusers will only be able to see tables that they have permission to access

Column	Description
skcoid	The object id of the table.
skcnamespace	The namespace where the table is defined.
skcrelname	The table name.
skccoeff	The coefficient of variation (CV) is calculated as the standard deviation divided by the average. It takes into account both the average and variability around the average of a data series. The lower the value, the better. Higher values indicate greater data skew.

gp_skew_idle_fractions

This view shows data distribution skew by calculating the percentage of the system that is idle during a table scan, which is an indicator of processing data skew. This view is accessible to all users, however non-superusers will only be able to see tables that they have permission to access

Column	Description
sifoid	The object id of the table.
sifnamespace	The namespace where the table is defined.
sifrelname	The table name.
siffraction	The percentage of the system that is idle during a table scan, which is an indicator of uneven data distribution or query processing skew. For example, a value of 0.1 indicates 10% skew, a value of 0.5 indicates 50% skew, and so on. Tables that have more than 10% skew should have their distribution policies evaluated.

Maintaining Partitions

If your database employs partitions you will need to perform certain tasks regularly to help maintain those partitions. WarehousePG includes a view and a number of user-defined functions to help with these tasks.

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The gp_partitions View

The `gp_partitions` view shows all leaf partitions in a database.

This view provides backwards compatibility with the legacy `pg_partitions` view (available in earlier major versions of WarehousePG).

Column	Type	Description
schemaname	name	The name of the schema the partitioned table is in.
tablename	name	The name of the top-level parent table.
partitionschemaname	name	The schema of the partition table.
partitiontablename	name	The relation name of the partitioned table (this is the table name to use if accessing the partition directly).
parentpartitiontablename	regclass	The relation name of the parent table one level up from this partition.
partitiontype	text	The type of partition (range or list).
partitionlevel	integer	The level of this partition in the hierarchy.
partitionrank	integer	For range partitions, the rank of the partition compared to other partitions of the same level.
partitionlistvalues	text	For list partitions, the list value(s) associated with this partition.
partitionrangestart	text	For range partitions, the start value of this partition.
partitionrangeend	text	For range partitions, the end value of this partition.
partitionisdefault	boolean	T if this is a default partition, otherwise F.
partitionboundary	text	The entire partition specification for this partition.
parenttablespace	name	The tablespace of the parent table one level up from this partition.
partitiontablespace	name	The tablespace of this partition.

User-Defined Functions for Partition Maintenance

The following table summarizes the functions WarehousePG provides to help you maintain partitions:

Function	Return Type	Description
`pg_partition_rank(rp regclass)`	integer	For range partitions, returns the rank of the partition compared to other partitions of the same level.For other partition types, it returns `NULL`.
`pg_partition_range_from(rp regclass)`	text	Returns the lower bound of a range partition.
`pg_partition_range_to(rp regclass)`	text	Returns the upper bound of a range partition.
`pg_partition_bound_value(rp regclass)`	text	Returns a textual representation of the bounds of a range partition.
`pg_partition_isdefault(rp regclass)`	boolean	Evaluates whether a given partition is a default partition.
`pg_partition_lowest_child(rp regclass)`	regclass	Finds the lowest ranked child of given partition.
`pg_partition_highest_child(rp regclass)`	regclass	Finds the highest ranked child of given partition.

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7.10 SQL Features, Reserved and Key Words, and Compliance

This section includes topics that identify SQL features and compliance in WarehousePG:

- Summary of WarehousePG Features
- Reserved Identifiers and SQL Key Words
- SQL 2008 Optional Feature Compliance

Parent topic: WarehousePG Reference Guide

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7.10.1 Summary of WarehousePG Features

This section provides a high-level overview of the system requirements and feature set of WarehousePG. It contains the following topics:

- WarehousePG SQL Standard Conformance
- WarehousePG and PostgreSQL Compatibility

WarehousePG SQL Standard Conformance

The SQL language was first formally standardized in 1986 by the American National Standards Institute (ANSI) as SQL 1986. Subsequent versions of the SQL standard have been released by ANSI and as International Organization for Standardization (ISO) standards: SQL 1989, SQL 1992, SQL 1999, SQL 2003, SQL 2006, and finally SQL 2008, which is the current SQL standard. The official name of the standard is ISO/IEC 9075-14:2008. In general, each new version adds more features, although occasionally features are deprecated or removed.

It is important to note that there are no commercial database systems that are fully compliant with the SQL standard. WarehousePG is almost fully compliant with the SQL 1992 standard, with most of the features from SQL 1999. Several features from SQL 2003 have also been implemented (most notably the SQL OLAP features).

This section addresses the important conformance issues of WarehousePG as they relate to the SQL standards. For a feature-by-feature list of WarehousePG's support of the latest SQL standard, see SQL 2008 Optional Feature Compliance.

Core SQL Conformance

In the process of building a parallel, shared-nothing database system and query optimizer, certain common SQL constructs are not currently implemented in WarehousePG. The following SQL constructs are not supported:

1. Some set returning subqueries in `EXISTS` or `NOT EXISTS` clauses that WarehousePG's parallel optimizer cannot rewrite into joins.
2. Backwards scrolling cursors, including the use of `FETCH PRIOR`, `FETCH FIRST`, `FETCH ABSOLUTE`, and `FETCH RELATIVE`.
3. In `CREATE TABLE` statements (on hash-distributed tables): a `UNIQUE` or `PRIMARY KEY` clause must include all of (or a superset of) the distribution key columns. Because of this restriction, only one `UNIQUE` clause or `PRIMARY KEY` clause is allowed in a `CREATE TABLE` statement. `UNIQUE` or `PRIMARY KEY` clauses are not allowed on randomly-distributed tables.
4. `CREATE UNIQUE INDEX` statements that do not contain all of (or a superset of) the distribution key columns. `CREATE UNIQUE INDEX` is not allowed on randomly-distributed tables.

   Note that `UNIQUE INDEXES` (but not `UNIQUE CONSTRAINTS`) are enforced on a part basis within a partitioned table. They guarantee the uniqueness of the key within each part or sub-part.
5. `VOLATILE` or `STABLE` functions cannot run on the segments, and so are generally limited to being passed literal values as the arguments to their parameters.
6. Triggers are not generally supported because they typically rely on the use of `VOLATILE` functions. PostgreSQL Event Triggers are supported because they capture only DDL events.
7. Referential integrity constraints (foreign keys) are not enforced in WarehousePG. Users can declare foreign keys and this information is kept in the system catalog, however.
8. Sequence manipulation functions `CURRVAL` and `LASTVAL`.

SQL 1992 Conformance

The following features of SQL 1992 are not supported in WarehousePG:

1. `NATIONAL CHARACTER` (`NCHAR`) and `NATIONAL CHARACTER VARYING` (`NVARCHAR`). Users can declare the `NCHAR` and `NVARCHAR` types, however they are just synonyms for `CHAR` and `VARCHAR` in WarehousePG.
2. `CREATE ASSERTION` statement.
3. `INTERVAL` literals are supported in WarehousePG, but do not conform to the standard.
4. `GET DIAGNOSTICS` statement.
5. `GLOBAL TEMPORARY TABLE`s and `LOCAL TEMPORARY TABLE`s. WarehousePG `TEMPORARY TABLE`s do not conform to the SQL standard, but many commercial database systems have implemented temporary tables in the same way. WarehousePG temporary tables are the same as `VOLATILE TABLE`s in Teradata.
6. `UNIQUE` predicate.
7. `MATCH PARTIAL` for referential integrity checks (most likely will not be implemented in WarehousePG).

SQL 1999 Conformance

The following features of SQL 1999 are not supported in WarehousePG:

1. Large Object data types: `BLOB`, `CLOB`, `NCLOB`. However, the `BYTEA` and `TEXT` columns can store very large amounts of data in WarehousePG (hundreds of megabytes).
2. `MODULE` (SQL client modules).
3. `CREATE PROCEDURE` (`SQL/PSM`). This can be worked around in WarehousePG by creating a `FUNCTION` that returns `void`, and invoking the function as follows:

   ```
   SELECT *myfunc*(*args*);
   ```
4. The PostgreSQL/WarehousePG function definition language (`PL/PGSQL`) is a subset of Oracle's `PL/SQL`, rather than being compatible with the `SQL/PSM` function definition language. WarehousePG also supports function definitions written in Python, Perl, Java, and R.
5. `BIT` and `BIT VARYING` data types (intentionally omitted). These were deprecated in SQL 2003, and replaced in SQL 2008.
6. WarehousePG supports identifiers up to 63 characters long. The SQL standard requires support for identifiers up to 128 characters long.
7. Prepared transactions (`PREPARE TRANSACTION`, `COMMIT PREPARED`, `ROLLBACK PREPARED`). This also means WarehousePG does not support `XA` Transactions (2 phase commit coordination of database transactions with external transactions).

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8. `CHARACTER SET` option on the definition of `CHAR()` or `VARCHAR()` columns.
9. Specification of `CHARACTERS` or `OCTETS` (`BYTES`) on the length of a `CHAR()` or `VARCHAR()` column. For example, `VARCHAR(15 CHARACTERS)` or `VARCHAR(15 OCTETS)` or `VARCHAR(15 BYTES)`.
10. `CREATE DISTINCT TYPE` statement. `CREATE DOMAIN` can be used as a work-around in WarehousePG.
11. The *explicit table* construct.

SQL 2003 Conformance

The following features of SQL 2003 are not supported in WarehousePG:

1. `MERGE` statements.
2. `IDENTITY` columns and the associated `GENERATED ALWAYS/GENERATED BY DEFAULT` clause. The `SERIAL` or `BIGSERIAL` data types are very similar to `INT` or `BIGINT GENERATED BY DEFAULT AS IDENTITY`.
3. `MULTISET` modifiers on data types.
4. `ROW` data type.
5. WarehousePG syntax for using sequences is non-standard. For example, `nextval('seq')` is used in WarehousePG instead of the standard `NEXT VALUE FOR seq`.
6. `GENERATED ALWAYS AS` columns. Views can be used as a work-around.
7. The sample clause (`TABLESAMPLE`) on `SELECT` statements. The `random()` function can be used as a work-around to get random samples from tables.
8. The *partitioned join tables* construct (`PARTITION BY` in a join).
9. WarehousePG cluster data types are almost SQL standard compliant with some exceptions. Generally customers should not encounter any problems using them.

SQL 2008 Conformance

The following features of SQL 2008 are not supported in WarehousePG:

1. `BINARY` and `VARBINARY` data types. `BYTEA` can be used in place of `VARBINARY` in WarehousePG.
2. The `ORDER BY` clause is ignored in views and subqueries unless a `LIMIT` clause is also used. This is intentional, as the WarehousePG optimizer cannot determine when it is safe to avoid the sort, causing an unexpected performance impact for such `ORDER BY` clauses. To work around, you can specify a really large `LIMIT`. For example:

   ```
   SELECT * FROM mytable ORDER BY 1 LIMIT 9999999999
   ```

3. The *row subquery* construct is not supported.
4. `TRUNCATE TABLE` does not accept the `CONTINUE IDENTITY` and `RESTART IDENTITY` clauses.

WarehousePG and PostgreSQL Compatibility

WarehousePG is based on PostgreSQL 9.4. To support the distributed nature and typical workload of a WarehousePG cluster, some SQL commands have been added or modified, and there are a few PostgreSQL features that are not supported. WarehousePG has also added features not found in PostgreSQL, such as physical data distribution, parallel query optimization, external tables, resource queues, and enhanced table partitioning. For full SQL syntax and references, see the SQL Commands.

> **Note** WarehousePG does not support the PostgreSQL large object facility for streaming user data that is stored in large-object structures.

> **Note** Unsupported: using `WITH OIDS` or `oids=TRUE` to assign an OID system column when creating or altering a table. This syntax is deprecated and will be removed in a future WarehousePG release.

WarehousePG and PostgreSQL Compatibility SQL Support

SQL Command	Supported in WarehousePG	Modifications, Limitations, Exceptions
`ALTER AGGREGATE`	YES	
`ALTER CONVERSION`	YES	
`ALTER DATABASE`	YES	
`ALTER DOMAIN`	YES	
`ALTER EVENT TRIGGER`	YES	
`ALTER EXTENSION`	YES	Changes the definition of a WarehousePG extension - based on PostgreSQL 9.6.
`ALTER FUNCTION`	YES	
`ALTER GROUP`	YES	An alias for ALTER ROLE
`ALTER INDEX`	YES	
`ALTER LANGUAGE`	YES	
`ALTER OPERATOR`	YES	
`ALTER OPERATOR CLASS`	YES	
`ALTER OPERATOR FAMILY`	YES	
`ALTER PROTOCOL`	YES	
`ALTER PUBLICATION`	NO	

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`ALTER RESOURCE QUEUE`	YES	WarehousePG resource management feature - not in PostgreSQL.
`ALTER ROLE`	YES	**WarehousePG Clauses:** `RESOURCE QUEUE` *queue_name* | `none`
`ALTER SCHEMA`	YES	
`ALTER SEQUENCE`	YES	
`ALTER SUBSCRIPTION`	NO	
`ALTER SYSTEM`	**NO**	

`ALTER TABLE`	YES	**Unsupported Clauses / Options:**
		`ENABLE/DISABLE TRIGGER`
		WarehousePG Database Clauses:
		`ADD | DROP | RENAME | SPLIT | EXCHANGE PARTITION | SET SUBPARTITION TEMPLATE | SET WITH (REORGANIZE=true | false) | SET DISTRIBUTED BY`

`ALTER TABLESPACE`	YES	
`ALTER TRIGGER`	**NO**	
`ALTER TYPE`	YES	**WarehousePG Clauses:** `SET DEFAULT ENCODING`
`ALTER USER`	YES	An alias for ALTER ROLE
`ALTER VIEW`	YES	
`ANALYZE`	YES	
`BEGIN`	YES	
`CHECKPOINT`	YES	
`CLOSE`	YES	
`CLUSTER`	YES	
`COMMENT`	YES	
`COMMIT`	YES	
`COMMIT PREPARED`	**NO**	

`COPY`	YES	**Modified Clauses:**
		`ESCAPE [ AS ] '` *escape* `' | 'OFF'`
		WarehousePG Clauses:
		`[LOG ERRORS] SEGMENT REJECT LIMIT` *count* `[ROWS|PERCENT]`

`CREATE AGGREGATE`	YES	**Unsupported Clauses / Options:**
		`[ , SORTOP =` *sort_operator* `]`
		WarehousePG Clauses:
		`[ , COMBINEFUNC =` *combinefunc* `]`
		Limitations:
		The functions used to implement the aggregate must be `IMMUTABLE` functions.

`CREATE CAST`	YES	
`CREATE CONSTRAINT TRIGGER`	**NO**	
`CREATE CONVERSION`	YES	
`CREATE DATABASE`	YES	
`CREATE DOMAIN`	YES	
`CREATE EVENT TRIGGER`	YES	
`CREATE EXTENSION`	YES	Loads a new extension into WarehousePG - based on PostgreSQL 9.6.

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`CREATE EXTERNAL TABLE`	YES	WarehousePG parallel ETL feature - not in PostgreSQL 9.4.
`CREATE FUNCTION`	YES	**Limitations:** Functions defined as `STABLE` or `VOLATILE` can be run in WarehousePG provided that they are run on the coordinator only. `STABLE` and `VOLATILE` functions cannot be used in statements that run at the segment level.
`CREATE GROUP`	YES	An alias for CREATE ROLE
`CREATE INDEX`	YES	**WarehousePG Clauses:** `USING bitmap` (bitmap indexes) **Limitations:** `UNIQUE` indexes are allowed only if they contain all of (or a superset of) the WarehousePG distribution key columns. On partitioned tables, a unique index is only supported within an individual partition - not across all partitions. `CONCURRENTLY` keyword not supported in WarehousePG.
`CREATE LANGUAGE`	YES	
`CREATE MATERIALIZED VIEW`	YES	Based on PostgreSQL 9.4.
`CREATE OPERATOR`	YES	**Limitations:** The function used to implement the operator must be an `IMMUTABLE` function.
`CREATE OPERATOR CLASS`	YES	
`CREATE OPERATOR FAMILY`	YES	
`CREATE PROTOCOL`	YES	
`CREATE PUBLICATION`	NO	
`CREATE RESOURCE QUEUE`	YES	WarehousePG resource management feature - not in PostgreSQL 9.4.
`CREATE ROLE`	YES	**WarehousePG Clauses:** `RESOURCE QUEUE` *queue_name* `| none`
`CREATE RULE`	YES	
`CREATE SCHEMA`	YES	
`CREATE SEQUENCE`	YES	**Limitations:** The `lastval()` and `currval()` functions are not supported. The `setval()` function is only allowed in queries that do not operate on distributed data.
`CREATE SUBSCRIPTION`	NO	

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		Unsupported Clauses / Options:
		`[GLOBAL | LOCAL]`
		`REFERENCES`
		`FOREIGN KEY`
		`[DEFERRABLE | NOT DEFERRABLE]`
		Limited Clauses:
		`UNIQUE` or `PRIMARY KEY` constraints are only allowed on hash-distributed tables (`DISTRIBUTED BY`), and the constraint columns must be the same as or a superset of the distribution key columns of the table and must include all the distribution key columns of the partitioning key.
		WarehousePG Clauses:
		`DISTRIBUTED BY (column, [ ... ] ) |`
		`DISTRIBUTED RANDOMLY`
		`PARTITION BY type (column [, ...]) ( partition_specification, [...] )`
		`WITH (appendoptimized=true [,compresslevel=value,blocksize=value] )`

`CREATE TABLE`	YES	
`CREATE TABLE AS`	YES	See CREATE TABLE
`CREATE TABLESPACE`	**YES**	**WarehousePG Clauses:** Specify host file system locations for specific segment instances. `WITH (contentID_1='/path/to/dir1...)`
`CREATE TRIGGER`	**NO**	
`CREATE TYPE`	YES	**WarehousePG Clauses:** `COMPRESSTYPE | COMPRESSLEVEL | BLOCKSIZE` **Limitations:** The functions used to implement a new base type must be `IMMUTABLE` functions.
`CREATE USER`	YES	An alias for CREATE ROLE
`CREATE VIEW`	YES	
`DEALLOCATE`	YES	

`DECLARE`	YES	**Unsupported Clauses / Options:**
		`SCROLL`
		`FOR UPDATE [ OF column [, ...] ]`
		Limitations:
		Cursors cannot be backward-scrolled. Forward scrolling is supported.
		PL/pgSQL does not have support for updatable cursors.

`DELETE`	YES	
`DISCARD`	YES	**Limitation:** `DISCARD ALL` is not supported.
`DO`	YES	PostgreSQL 9.0 feature
`DROP AGGREGATE`	YES	
`DROP CAST`	YES	
`DROP CONVERSION`	YES	
`DROP DATABASE`	YES	
`DROP DOMAIN`	YES	
`DROP EVENT TRIGGER`	YES	

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`DROP EXTENSION`	YES	Removes an extension from WarehousePG – based on PostgreSQL 9.6.
`DROP EXTERNAL TABLE`	YES	WarehousePG parallel ETL feature - not in PostgreSQL 9.4.
`DROP FUNCTION`	YES	
`DROP GROUP`	YES	An alias for DROP ROLE
`DROP INDEX`	YES	
`DROP LANGUAGE`	YES	
`DROP OPERATOR`	YES	
`DROP OPERATOR CLASS`	YES	
`DROP OPERATOR FAMILY`	YES	
`DROP OWNED`	**NO**	
`DROP PROTOCOL`	YES	
`DROP PUBLICATION`	NO	
`DROP RESOURCE QUEUE`	YES	WarehousePG resource management feature - not in PostgreSQL 9.4.
`DROP ROLE`	YES	
`DROP RULE`	YES	
`DROP SCHEMA`	YES	
`DROP SEQUENCE`	YES	
`DROP SUBSCRIPTION`	NO	
`DROP TABLE`	YES	
`DROP TABLESPACE`	YES	
`DROP TRIGGER`	**NO**	
`DROP TYPE`	YES	
`DROP USER`	YES	An alias for DROP ROLE
`DROP VIEW`	YES	
`END`	YES	
`EXECUTE`	YES	
`EXPLAIN`	YES	

`FETCH`	YES	**Unsupported Clauses / Options:**
		`LAST`
		`PRIOR`
		`BACKWARD`
		`BACKWARD ALL`
		Limitations:
		Cannot fetch rows in a nonsequential fashion; backward scan is not supported.

`GRANT`	YES	
`INSERT`	YES	
`LATERAL` Join Type	**NO**	
`LISTEN`	**YES**	
`LOAD`	YES	
`LOCK`	YES	
`MOVE`	YES	See FETCH
`NOTIFY`	**YES**	
`PREPARE`	YES	
`PREPARE TRANSACTION`	**NO**	
`REASSIGN OWNED`	YES	
`REFRESH MATERIALIZED VIEW`	YES	Based on PostgreSQL 9.4.
`REINDEX`	YES	
`RELEASE SAVEPOINT`	YES	
`RESET`	YES	
`RETRIEVE`	YES	WarehousePG parallel retrieve cursor - not in PostgreSQL 9.4.
`REVOKE`	YES	
`ROLLBACK`	YES	

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`ROLLBACK PREPARED`	**NO**	
`ROLLBACK TO SAVEPOINT`	YES	
`SAVEPOINT`	YES	

`SELECT`	YES	**Limitations:**
		Limited use of `VOLATILE` and `STABLE` functions in `FROM` or `WHERE` clauses
		Text search (`Tsearch2`) is not supported
		WarehousePG Clauses (OLAP):
		`[GROUP BY` *grouping_element* `[, ...]]`
		`[WINDOW` *window_name* `AS (` *window_specification* `)]`
		`[FILTER (WHERE` *condition* `)]` applied to an aggregate function in the `SELECT` list

`SELECT INTO`	YES	See SELECT
`SET`	YES	
`SET CONSTRAINTS`	**NO**	In PostgreSQL, this only applies to foreign key constraints, which are currently not enforced in WarehousePG.
`SET ROLE`	YES	
`SET SESSION AUTHORIZATION`	YES	Deprecated as of PostgreSQL 8.1 - see SET ROLE
`SET TRANSACTION`	YES	**Limitations:** `DEFERRABLE` clause has no effect.
`SHOW`	YES	
`START TRANSACTION`	YES	
`TRUNCATE`	YES	
`UNLISTEN`	**YES**	
`UPDATE`	YES	**Limitations:** `SET` not allowed for WarehousePG distribution key columns.
`VACUUM`	YES	**Limitations:** `VACUUM FULL` is not recommended in WarehousePG.
`VALUES`	YES	

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7.10.2 Reserved Identifiers and SQL Key Words

This topic describes WarehousePG reserved identifiers and object names, and SQL key words recognized by the WarehousePG and PostgreSQL command parsers.

Reserved Identifiers

In the WarehousePG cluster, names beginning with `gp_` and `pg_` are reserved and should not be used as names for user-created objects, such as tables, views, and functions.

The resource group names `admin_group`, `default_group`, and `none` are reserved. The resource queue name `pg_default` is reserved.

The tablespace names `pg_default` and `pg_global` are reserved.

The role name `gpadmin` is reserved. `gpadmin` is the default WarehousePG superuser role.

In data files, the characters that delimit fields (columns) and rows have a special meaning. If they appear within the data you must escape them so that WarehousePG treats them as data and not as delimiters. The backslash character (`\`) is the default escape character. See Escaping for details.

See SQL Syntax in the PostgreSQL documentation for more information about SQL identifiers, constants, operators, and expressions.

SQL Key Words

SQL keyword status lists all tokens that are key words in WarehousePG 6 and PostgreSQL 9.4.

ANSI SQL distinguishes between *reserved* and *unreserved* key words. According to the standard, reserved key words are the only real key words; they are never allowed as identifiers. Unreserved key words only have a special meaning in particular contexts and can be used as identifiers in other contexts. Most unreserved key words are actually the names of built-in tables and functions specified by SQL. The concept of unreserved key words essentially only exists to declare that some predefined meaning is attached to a word in some contexts.

In the WarehousePG and PostgreSQL parsers there are several different classes of tokens ranging from those that can never be used as an identifier to those that have absolutely no special status in the parser as compared to an ordinary identifier. (The latter is usually the case for functions specified by SQL.) Even reserved key words are not completely reserved, but can be used as column labels (for example, `SELECT 55 AS CHECK`, even though `CHECK` is a reserved key word).

SQL keyword status classifies as "unreserved" those key words that are explicitly known to the parser but are allowed as column or table names. Some key words that are otherwise unreserved cannot be used as function or data type names and are marked accordingly. (Most of these words represent built-in functions or data types with special syntax. The function or type is still available but it cannot be redefined by the user.) Key words labeled "reserved" are not allowed as column or table names. Some reserved key words are allowable as names for functions or data types; this is also shown in the table. If not so marked, a reserved key word is only allowed as an "AS" column label name.

If you get spurious parser errors for commands that contain any of the listed key words as an identifier you should try to quote the identifier to see if the problem goes away.

Before studying the table, note the fact that a key word is not reserved does not mean that the feature related to the word is not implemented. Conversely, the presence of a key word does not indicate the existence of a feature.

SQL keyword status

Key Word	WarehousePG	PostgreSQL 9.4
ABORT	unreserved	unreserved
ABSOLUTE	unreserved	unreserved
ACCESS	unreserved	unreserved
ACTION	unreserved	unreserved
ACTIVE	unreserved	
ADD	unreserved	unreserved
ADMIN	unreserved	unreserved
AFTER	unreserved	unreserved
AGGREGATE	unreserved	unreserved
ALL	reserved	reserved
ALSO	unreserved	unreserved
ALTER	unreserved	unreserved
ALWAYS	unreserved	unreserved
ANALYSE	reserved	reserved
ANALYZE	reserved	reserved
AND	reserved	reserved
ANY	reserved	reserved
ARRAY	reserved	reserved
AS	reserved	reserved
ASC	reserved	reserved
ASSERTION	unreserved	unreserved
ASSIGNMENT	unreserved	unreserved
ASYMMETRIC	reserved	reserved
AT	unreserved	unreserved
ATTRIBUTE	unreserved	unreserved
AUTHORIZATION	reserved (can be function or type name)	reserved (can be function or type name)
BACKWARD	unreserved	unreserved
BEFORE	unreserved	unreserved
BEGIN	unreserved	unreserved

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Key Word	WarehousePG	PostgreSQL 9.4
BETWEEN	unreserved (cannot be function or type name)	unreserved (cannot be function or type name)
BIGINT	unreserved (cannot be function or type name)	unreserved (cannot be function or type name)
BINARY	reserved (can be function or type name)	reserved (can be function or type name)
BIT	unreserved (cannot be function or type name)	unreserved (cannot be function or type name)
BOOLEAN	unreserved (cannot be function or type name)	unreserved (cannot be function or type name)
BOTH	reserved	reserved
BY	unreserved	unreserved
CACHE	unreserved	unreserved
CALLED	unreserved	unreserved
CASCADE	unreserved	unreserved
CASCADED	unreserved	unreserved
CASE	reserved	reserved
CAST	reserved	reserved
CATALOG	unreserved	unreserved
CHAIN	unreserved	unreserved
CHAR	unreserved (cannot be function or type name)	unreserved (cannot be function or type name)
CHARACTER	unreserved (cannot be function or type name)	unreserved (cannot be function or type name)
CHARACTERISTICS	unreserved	unreserved
CHECK	reserved	reserved
CHECKPOINT	unreserved	unreserved
CLASS	unreserved	unreserved
CLOSE	unreserved	unreserved
CLUSTER	unreserved	unreserved
COALESCE	unreserved (cannot be function or type name)	unreserved (cannot be function or type name)
COLLATE	reserved	reserved
COLLATION	reserved (can be function or type name)	reserved (can be function or type name)
COLUMN	reserved	reserved
COMMENT	unreserved	unreserved
COMMENTS	unreserved	unreserved
COMMIT	unreserved	unreserved
COMMITTED	unreserved	unreserved
CONCURRENCY	unreserved	
CONCURRENTLY	reserved (can be function or type name)	reserved (can be function or type name)
CONFIGURATION	unreserved	unreserved
CONFLICT	unreserved	unreserved
CONNECTION	unreserved	unreserved
CONSTRAINT	reserved	reserved
CONSTRAINTS	unreserved	unreserved
CONTAINS	unreserved	
CONTENT	unreserved	unreserved
CONTINUE	unreserved	unreserved
CONVERSION	unreserved	unreserved
COPY	unreserved	unreserved
COST	unreserved	unreserved
CPU_RATE_LIMIT	unreserved	
CPUSET	unreserved	
CREATE	reserved	reserved
CREATEEXTTABLE	unreserved	
CROSS	reserved (can be function or type name)	reserved (can be function or type name)
CSV	unreserved	unreserved
CUBE	unreserved (cannot be function or type name)	
CURRENT	unreserved	unreserved
CURRENT_CATALOG	reserved	reserved
CURRENT_DATE	reserved	reserved
CURRENT_ROLE	reserved	reserved
CURRENT_SCHEMA	reserved (can be function or type name)	reserved (can be function or type name)
CURRENT_TIME	reserved	reserved
CURRENT_TIMESTAMP	reserved	reserved
CURRENT_USER	reserved	reserved
CURSOR	unreserved	unreserved
CYCLE	unreserved	unreserved
DATA	unreserved	unreserved
DATABASE	unreserved	unreserved

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Key Word	WarehousePG	PostgreSQL 9.4
DAY	unreserved	unreserved
DEALLOCATE	unreserved	unreserved
DEC	unreserved (cannot be function or type name)	unreserved (cannot be function or type name)
DECIMAL	unreserved (cannot be function or type name)	unreserved (cannot be function or type name)
DECLARE	unreserved	unreserved
DECODE	reserved	
DEFAULT	reserved	reserved
DEFAULTS	unreserved	unreserved
DEFERRABLE	reserved	reserved
DEFERRED	unreserved	unreserved
DEFINER	unreserved	unreserved
DELETE	unreserved	unreserved
DELIMITER	unreserved	unreserved
DELIMITERS	unreserved	unreserved
DENY	unreserved	
DEPENDS	unreserved	unreserved
DESC	reserved	reserved
DICTIONARY	unreserved	unreserved
DISABLE	unreserved	unreserved
DISCARD	unreserved	unreserved
DISTINCT	reserved	reserved
DISTRIBUTED	reserved	
DO	reserved	reserved
DOCUMENT	unreserved	unreserved
DOMAIN	unreserved	unreserved
DOUBLE	unreserved	unreserved
DROP	unreserved	unreserved
DXL	unreserved	
EACH	unreserved	unreserved
ELSE	reserved	reserved
ENABLE	unreserved	unreserved
ENCODING	unreserved	unreserved
ENCRYPTED	unreserved	unreserved
END	reserved	reserved
ENDPOINT	unreserved	unreserved
ENUM	unreserved	unreserved
ERRORS	unreserved	
ESCAPE	unreserved	unreserved
EVENT	unreserved	unreserved
EVERY	unreserved	
EXCEPT	reserved	reserved
EXCHANGE	unreserved	
EXCLUDE	reserved	unreserved
EXCLUDING	unreserved	unreserved
EXCLUSIVE	unreserved	unreserved
EXECUTE	unreserved	unreserved
EXISTS	unreserved (cannot be function or type name)	unreserved (cannot be function or type name)
EXPAND	unreserved	
EXPLAIN	unreserved	unreserved
EXTENSION	unreserved	unreserved
EXTERNAL	unreserved	unreserved
EXTRACT	unreserved (cannot be function or type name)	unreserved (cannot be function or type name)
FALSE	reserved	reserved
FAMILY	unreserved	unreserved
FETCH	reserved	reserved
FIELDS	unreserved	
FILESPACE	unreserved	unreserved
FILL	unreserved	
FILTER	unreserved	unreserved
FIRST	unreserved	unreserved
FLOAT	unreserved (cannot be function or type name)	unreserved (cannot be function or type name)
FOLLOWING	reserved	unreserved
FOR	reserved	reserved
FORCE	unreserved	unreserved
FOREIGN	reserved	reserved

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Key Word	WarehousePG	PostgreSQL 9.4
FORMAT	unreserved	
FORWARD	unreserved	unreserved
FREEZE	reserved (can be function or type name)	reserved (can be function or type name)
FROM	reserved	reserved
FULL	reserved (can be function or type name)	reserved (can be function or type name)
FULLSCAN	unreserved	
FUNCTION	unreserved	unreserved
FUNCTIONS	unreserved	unreserved
GENERATED	unreserved	unreserved
GLOBAL	unreserved	unreserved
GRANT	reserved	reserved
GRANTED	unreserved	unreserved
GREATEST	unreserved (cannot be function or type name)	unreserved (cannot be function or type name)
GROUP	reserved	reserved
GROUP_ID	unreserved (cannot be function or type name)	
GROUPING	unreserved (cannot be function or type name)	
HANDLER	unreserved	unreserved
HASH	unreserved	
HAVING	reserved	reserved
HEADER	unreserved	unreserved
HOLD	unreserved	unreserved
HOST	unreserved	
HOUR	unreserved	unreserved
IDENTITY	unreserved	unreserved
IF	unreserved	unreserved
IGNORE	unreserved	
ILIKE	reserved (can be function or type name)	reserved (can be function or type name)
IMMEDIATE	unreserved	unreserved
IMMUTABLE	unreserved	unreserved
IMPLICIT	unreserved	unreserved
IMPORT	unreserved	unreserved
IN	reserved	reserved
INCLUDING	unreserved	unreserved
INCLUSIVE	unreserved	
INCREMENT	unreserved	unreserved
INDEX	unreserved	unreserved
INDEXES	unreserved	unreserved
INHERIT	unreserved	unreserved
INHERITS	unreserved	unreserved
INITIALLY	reserved	reserved
INITPLAN	unreserved	unreserved
INLINE	unreserved	unreserved
INNER	reserved (can be function or type name)	reserved (can be function or type name)
INOUT	unreserved (cannot be function or type name)	unreserved (cannot be function or type name)
INPUT	unreserved	unreserved
INSENSITIVE	unreserved	unreserved
INSERT	unreserved	unreserved
INSTEAD	unreserved	unreserved
INT	unreserved (cannot be function or type name)	unreserved (cannot be function or type name)
INTEGER	unreserved (cannot be function or type name)	unreserved (cannot be function or type name)
INTERSECT	reserved	reserved
INTERVAL	unreserved (cannot be function or type name)	unreserved (cannot be function or type name)
INTO	reserved	reserved
INVOKER	unreserved	unreserved
IS	reserved (can be function or type name)	reserved (can be function or type name)
ISNULL	reserved (can be function or type name)	reserved (can be function or type name)
ISOLATION	unreserved	unreserved
JOIN	reserved (can be function or type name)	reserved (can be function or type name)
KEY	unreserved	unreserved
LABEL	unreserved	unreserved
LANGUAGE	unreserved	unreserved
LARGE	unreserved	unreserved
LAST	unreserved	unreserved
LATERAL	reserved	reserved

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Key Word	WarehousePG	PostgreSQL 9.4
LC_COLLATE	unreserved	unreserved
LC_CTYPE	unreserved	unreserved
LEADING	reserved	reserved
LEAKPROOF	unreserved	unreserved
LEAST	unreserved (cannot be function or type name)	unreserved (cannot be function or type name)
LEFT	reserved (can be function or type name)	reserved (can be function or type name)
LEVEL	unreserved	unreserved
LIKE	reserved (can be function or type name)	reserved (can be function or type name)
LIMIT	reserved	reserved
LIST	unreserved	
LISTEN	unreserved	unreserved
LOAD	unreserved	unreserved
LOCAL	unreserved	unreserved
LOCALTIME	reserved	reserved
LOCALTIMESTAMP	reserved	reserved
LOCATION	unreserved	unreserved
LOCK	unreserved	unreserved
LOCKED	unreserved	unreserved
LOG	reserved (can be function or type name)	
LOGGED	unreserved	unreserved
MAPPING	unreserved	unreserved
MASTER	unreserved	
MATCH	unreserved	unreserved
MATERIALIZED	unreserved	unreserved
MAXVALUE	unreserved	unreserved
MEDIAN	unreserved (cannot be function or type name)	
MEMORY_LIMIT	unreserved	
MEMORY_SHARED_QUOTA	unreserved	
MEMORY_SPILL_RATIO	unreserved	
METHOD	unreserved	unreserved
MINUTE	unreserved	unreserved
MINVALUE	unreserved	unreserved
MISSING	unreserved	
MODE	unreserved	unreserved
MODIFIES	unreserved	
MONTH	unreserved	unreserved
MOVE	unreserved	unreserved
NAME	unreserved	unreserved
NAMES	unreserved	unreserved
NATIONAL	unreserved (cannot be function or type name)	unreserved (cannot be function or type name)
NATURAL	reserved (can be function or type name)	reserved (can be function or type name)
NCHAR	unreserved (cannot be function or type name)	unreserved (cannot be function or type name)
NEWLINE	unreserved	
NEXT	unreserved	unreserved
NO	unreserved	unreserved
NOCREATEEXTTABLE	unreserved	
NONE	unreserved (cannot be function or type name)	unreserved (cannot be function or type name)
NOOVERCOMMIT	unreserved	
NOT	reserved	reserved
NOTHING	unreserved	unreserved
NOTIFY	unreserved	unreserved
NOTNULL	reserved (can be function or type name)	reserved (can be function or type name)
NOWAIT	unreserved	unreserved
NULL	reserved	reserved
NULLIF	unreserved (cannot be function or type name)	unreserved (cannot be function or type name)
NULLS	unreserved	unreserved
NUMERIC	unreserved (cannot be function or type name)	unreserved (cannot be function or type name)
OBJECT	unreserved	unreserved
OF	unreserved	unreserved
OFF	unreserved	unreserved
OFFSET	reserved	reserved
OIDS	unreserved	unreserved
ON	reserved	reserved
ONLY	reserved	reserved

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Key Word	WarehousePG	PostgreSQL 9.4
OPERATOR	unreserved	unreserved
OPTION	unreserved	unreserved
OPTIONS	unreserved	unreserved
OR	reserved	reserved
ORDER	reserved	reserved
ORDERED	unreserved	
ORDINALITY	unreserved	unreserved
OTHERS	unreserved	
OUT	unreserved (cannot be function or type name)	unreserved (cannot be function or type name)
OUTER	reserved (can be function or type name)	reserved (can be function or type name)
OVER	unreserved	unreserved
OVERCOMMIT	unreserved	
OVERLAPS	reserved (can be function or type name)	reserved (can be function or type name)
OVERLAY	unreserved (cannot be function or type name)	unreserved (cannot be function or type name)
OWNED	unreserved	unreserved
OWNER	unreserved	unreserved
PARALLEL	unreserved	unreserved
PARSER	unreserved	unreserved
PARTIAL	unreserved	unreserved
PARTITION	reserved	unreserved
PARTITIONS	unreserved	
PASSING	unreserved	unreserved
PASSWORD	unreserved	unreserved
PERCENT	unreserved	
PLACING	reserved	reserved
PLANS	unreserved	unreserved
POLICY	unreserved	unreserved
POSITION	unreserved (cannot be function or type name)	unreserved (cannot be function or type name)
PRECEDING	reserved	unreserved
PRECISION	unreserved (cannot be function or type name)	unreserved (cannot be function or type name)
PREPARE	unreserved	unreserved
PREPARED	unreserved	unreserved
PRESERVE	unreserved	unreserved
PRIMARY	reserved	reserved
PRIOR	unreserved	unreserved
PRIVILEGES	unreserved	unreserved
PROCEDURAL	unreserved	unreserved
PROCEDURE	unreserved	unreserved
PROGRAM	unreserved	unreserved
PROTOCOL	unreserved	
QUEUE	unreserved	
QUOTE	unreserved	unreserved
RANDOMLY	unreserved	
RANGE	unreserved	unreserved
READ	unreserved	unreserved
READABLE	unreserved	
READS	unreserved	
REAL	unreserved (cannot be function or type name)	unreserved (cannot be function or type name)
REASSIGN	unreserved	unreserved
RECHECK	unreserved	unreserved
RECURSIVE	unreserved	unreserved
REF	unreserved	unreserved
REFERENCES	reserved	reserved
REFRESH	unreserved	unreserved
REINDEX	unreserved	unreserved
REJECT	unreserved	
RELATIVE	unreserved	unreserved
RELEASE	unreserved	unreserved
RENAME	unreserved	unreserved
REPEATABLE	unreserved	unreserved
REPLACE	unreserved	unreserved
REPLICA	unreserved	unreserved
REPLICATED	unreserved	
RESET	unreserved	unreserved
RESOURCE	unreserved	

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Key Word	WarehousePG	PostgreSQL 9.4
RESTART	unreserved	unreserved
RESTRICT	unreserved	unreserved
RETRIEVE	unreserved	unreserved
RETURNING	reserved	reserved
RETURNS	unreserved	unreserved
REVOKE	unreserved	unreserved
RIGHT	reserved (can be function or type name)	reserved (can be function or type name)
ROLE	unreserved	unreserved
ROLLBACK	unreserved	unreserved
ROLLUP	unreserved (cannot be function or type name)	
ROOTPARTITION	unreserved	
ROW	unreserved (cannot be function or type name)	unreserved (cannot be function or type name)
ROWS	unreserved	unreserved
RULE	unreserved	unreserved
SAVEPOINT	unreserved	unreserved
SCATTER	reserved	
SCHEMA	unreserved	unreserved
SCROLL	unreserved	unreserved
SEARCH	unreserved	unreserved
SECOND	unreserved	unreserved
SECURITY	unreserved	unreserved
SEGMENT	unreserved	
SEGMENTS	unreserved	
SELECT	reserved	reserved
SEQUENCE	unreserved	unreserved
SEQUENCES	unreserved	unreserved
SERIALIZABLE	unreserved	unreserved
SERVER	unreserved	unreserved
SESSION	unreserved	unreserved
SESSION_USER	reserved	reserved
SET	unreserved	unreserved
SETOF	unreserved (cannot be function or type name)	unreserved (cannot be function or type name)
SETS	unreserved (cannot be function or type name)	
SHARE	unreserved	unreserved
SHOW	unreserved	unreserved
SIMILAR	reserved (can be function or type name)	reserved (can be function or type name)
SIMPLE	unreserved	unreserved
SKIP	unreserved	unreserved
SMALLINT	unreserved (cannot be function or type name)	unreserved (cannot be function or type name)
SNAPSHOT	unreserved	unreserved
SOME	reserved	reserved
SPLIT	unreserved	
SQL	unreserved	
STABLE	unreserved	unreserved
STANDALONE	unreserved	unreserved
START	unreserved	unreserved
STATEMENT	unreserved	unreserved
STATISTICS	unreserved	unreserved
STDIN	unreserved	unreserved
STDOUT	unreserved	unreserved
STORAGE	unreserved	unreserved
STORED	unreserved	unreserved
STRICT	unreserved	unreserved
STRIP	unreserved	unreserved
SUBPARTITION	unreserved	
SUBSTRING	unreserved (cannot be function or type name)	unreserved (cannot be function or type name)
SYMMETRIC	reserved	reserved
SYSID	unreserved	unreserved
SYSTEM	unreserved	unreserved
TABLE	reserved	reserved
TABLES	unreserved	unreserved
TABLESPACE	unreserved	unreserved
TEMP	unreserved	unreserved
TEMPLATE	unreserved	unreserved

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Key Word	WarehousePG	PostgreSQL 9.4
TEMPORARY	unreserved	unreserved
TEXT	unreserved	unreserved
THEN	reserved	reserved
THRESHOLD	unreserved	
TIES	unreserved	
TIME	unreserved (cannot be function or type name)	unreserved (cannot be function or type name)
TIMESTAMP	unreserved (cannot be function or type name)	unreserved (cannot be function or type name)
TO	reserved	reserved
TRAILING	reserved	reserved
TRANSACTION	unreserved	unreserved
TRANSFORM	unreserved	unreserved
TREAT	unreserved (cannot be function or type name)	unreserved (cannot be function or type name)
TRIGGER	unreserved	unreserved
TRIM	unreserved (cannot be function or type name)	unreserved (cannot be function or type name)
TRUE	reserved	reserved
TRUNCATE	unreserved	unreserved
TRUSTED	unreserved	unreserved
TYPE	unreserved	unreserved
TYPES	unreserved	unreserved
UNBOUNDED	reserved	unreserved
UNCOMMITTED	unreserved	unreserved
UNENCRYPTED	unreserved	unreserved
UNION	reserved	reserved
UNIQUE	reserved	reserved
UNKNOWN	unreserved	unreserved
UNLISTEN	unreserved	unreserved
UNLOGGED	unreserved	unreserved
UNTIL	unreserved	unreserved
UPDATE	unreserved	unreserved
USER	reserved	reserved
USING	reserved	reserved
VACUUM	unreserved	unreserved
VALID	unreserved	unreserved
VALIDATE	unreserved	unreserved
VALIDATION	unreserved	
VALIDATOR	unreserved	unreserved
VALUE	unreserved	unreserved
VALUES	unreserved (cannot be function or type name)	unreserved (cannot be function or type name)
VARCHAR	unreserved (cannot be function or type name)	unreserved (cannot be function or type name)
VARIADIC	reserved	reserved
VARYING	unreserved	unreserved
VERBOSE	reserved (can be function or type name)	reserved (can be function or type name)
VERSION	unreserved	unreserved
VIEW	unreserved	unreserved
VIEWS	unreserved	unreserved
VOLATILE	unreserved	unreserved
WEB	unreserved	
WHEN	reserved	reserved
WHERE	reserved	reserved
WHITESPACE	unreserved	unreserved
WINDOW	reserved	reserved
WITH	reserved	reserved
WITHIN	unreserved	unreserved
WITHOUT	unreserved	unreserved
WORK	unreserved	unreserved
WRAPPER	unreserved	unreserved
WRITABLE	unreserved	
WRITE	unreserved	unreserved
XML	unreserved	unreserved
XMLATTRIBUTES	unreserved (cannot be function or type name)	unreserved (cannot be function or type name)
XMLCONCAT	unreserved (cannot be function or type name)	unreserved (cannot be function or type name)
XMLELEMENT	unreserved (cannot be function or type name)	unreserved (cannot be function or type name)

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Key Word	WarehousePG	PostgreSQL 9.4
XMLEXISTS	unreserved (cannot be function or type name)	unreserved (cannot be function or type name)
XMLFOREST	unreserved (cannot be function or type name)	unreserved (cannot be function or type name)
XMLPARSE	unreserved (cannot be function or type name)	unreserved (cannot be function or type name)
XMLPI	unreserved (cannot be function or type name)	unreserved (cannot be function or type name)
XMLROOT	unreserved (cannot be function or type name)	unreserved (cannot be function or type name)
XMLSERIALIZE	unreserved (cannot be function or type name)	unreserved (cannot be function or type name)
YEAR	unreserved	unreserved
YES	unreserved	unreserved
ZONE	unreserved	unreserved

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7.10.3 SQL 2008 Optional Feature Compliance

The following table lists the features described in the 2008 SQL standard. Features that are supported in WarehousePG are marked as YES in the 'Supported' column, features that are not implemented are marked as NO.

For information about WarehousePG features and SQL compliance, see the *WarehousePG Administrator Guide*.

ID	Feature	Supported	Comments
B011	Embedded Ada	NO	
B012	Embedded C	NO	Due to issues with PostgreSQL `ecpg`
B013	Embedded COBOL	NO	
B014	Embedded Fortran	NO	
B015	Embedded MUMPS	NO	
B016	Embedded Pascal	NO	
B017	Embedded PL/I	NO	
B021	Direct SQL	YES	
B031	Basic dynamic SQL	NO	
B032	Extended dynamic SQL	NO	
B033	Untyped SQL-invoked function arguments	NO	
B034	Dynamic specification of cursor attributes	NO	
B035	Non-extended descriptor names	NO	
B041	Extensions to embedded SQL exception declarations	NO	
B051	Enhanced execution rights	NO	
B111	Module language Ada	NO	
B112	Module language C	NO	
B113	Module language COBOL	NO	
B114	Module language Fortran	NO	
B115	Module language MUMPS	NO	
B116	Module language Pascal	NO	
B117	Module language PL/I	NO	
B121	Routine language Ada	NO	
B122	Routine language C	NO	
B123	Routine language COBOL	NO	
B124	Routine language Fortran	NO	
B125	Routine language MUMPS	NO	
B126	Routine language Pascal	NO	
B127	Routine language PL/I	NO	
B128	Routine language SQL	NO	
E011	Numeric data types	YES	
E011-01	`INTEGER` and `SMALLINT` data types	YES	
E011-02	`DOUBLE PRECISION` and `FLOAT` data types	YES	
E011-03	`DECIMAL` and `NUMERIC` data types	YES	
E011-04	Arithmetic operators	YES	
E011-05	Numeric comparison	YES	
E011-06	Implicit casting among the numeric data types	YES	
E021	Character data types	YES	
E021-01	`CHARACTER` data type	YES	
E021-02	`CHARACTER VARYING` data type	YES	
E021-03	Character literals	YES	
E021-04	`CHARACTER_LENGTH` function	YES	Trims trailing spaces from `CHARACTER` values before counting
E021-05	`OCTET_LENGTH` function	YES	
E021-06	`SUBSTRING` function	YES	
E021-07	Character concatenation	YES	
E021-08	`UPPER` and `LOWER` functions	YES	
E021-09	`TRIM` function	YES	
E021-10	Implicit casting among the character string types	YES	
E021-11	`POSITION` function	YES	

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ID	Feature	Supported	Comments
E021-12	Character comparison	YES	
E031	Identifiers	YES	
E031-01	Delimited identifiers	YES	
E031-02	Lower case identifiers	YES	
E031-03	Trailing underscore	YES	
E051	Basic query specification	YES	
E051-01	`SELECT DISTINCT`	YES	
E051-02	`GROUP BY` clause	YES	
E051-03	`GROUP BY` can contain columns not in `SELECT` list	YES	
E051-04	`SELECT` list items can be renamed	YES	
E051-05	`HAVING` clause	YES	
E051-06	Qualified * in `SELECT` list	YES	
E051-07	Correlation names in the `FROM` clause	YES	
E051-08	Rename columns in the `FROM` clause	YES	
E061	Basic predicates and search conditions	YES	
E061-01	Comparison predicate	YES	
E061-02	`BETWEEN` predicate	YES	
E061-03	`IN` predicate with list of values	YES	
E061-04	`LIKE` predicate	YES	
E061-05	`LIKE` predicate `ESCAPE` clause	YES	
E061-06	`NULL` predicate	YES	
E061-07	Quantified comparison predicate	YES	
E061-08	`EXISTS` predicate	YES	Not all uses work in WarehousePG
E061-09	Subqueries in comparison predicate	YES	
E061-11	Subqueries in IN predicate	YES	
E061-12	Subqueries in quantified comparison predicate	YES	
E061-13	Correlated subqueries	YES	
E061-14	Search condition	YES	
E071	Basic query expressions	YES	
E071-01	`UNION DISTINCT` table operator	YES	
E071-02	`UNION ALL` table operator	YES	
E071-03	`EXCEPT DISTINCT` table operator	YES	
E071-05	Columns combined via table operators need not have exactly the same data type	YES	
E071-06	Table operators in subqueries	YES	
E081	Basic Privileges	NO	Partial sub-feature support
E081-01	`SELECT` privilege	YES	
E081-02	`DELETE` privilege	YES	
E081-03	`INSERT` privilege at the table level	YES	
E081-04	`UPDATE` privilege at the table level	YES	
E081-05	`UPDATE` privilege at the column level	YES	
E081-06	`REFERENCES` privilege at the table level	NO	
E081-07	`REFERENCES` privilege at the column level	NO	

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ID	Feature	Supported	Comments
E081-08	`WITH GRANT OPTION`	YES	
E081-09	`USAGE` privilege	YES	
E081-10	`EXECUTE` privilege	YES	
E091	Set Functions	YES	
E091-01	`AVG`	YES	
E091-02	`COUNT`	YES	
E091-03	`MAX`	YES	
E091-04	`MIN`	YES	
E091-05	`SUM`	YES	
E091-06	`ALL` quantifier	YES	
E091-07	`DISTINCT` quantifier	YES	
E101	Basic data manipulation	YES	
E101-01	`INSERT` statement	YES	
E101-03	Searched `UPDATE` statement	YES	
E101-04	Searched `DELETE` statement	YES	
E111	Single row `SELECT` statement	YES	
E121	Basic cursor support	YES	
E121-01	`DECLARE CURSOR`	YES	
E121-02	`ORDER BY` columns need not be in select list	YES	
E121-03	Value expressions in `ORDER BY` clause	YES	
E121-04	`OPEN` statement	YES	
E121-06	Positioned `UPDATE` statement	NO	
E121-07	Positioned `DELETE` statement	NO	
E121-08	`CLOSE` statement	YES	
E121-10	`FETCH` statement implicit `NEXT`	YES	
E121-17	`WITH HOLD` cursors	YES	
E131	Null value support	YES	
E141	Basic integrity constraints	YES	
E141-01	`NOT NULL` constraints	YES	
E141-02	`UNIQUE` constraints of `NOT NULL` columns	YES	Must be the same as or a superset of the WarehousePG distribution key
E141-03	`PRIMARY KEY` constraints	YES	Must be the same as or a superset of the WarehousePG distribution key
E141-04	Basic `FOREIGN KEY` constraint with the `NO ACTION` default for both referential delete action and referential update action	NO	
E141-06	`CHECK` constraints	YES	
E141-07	Column defaults	YES	
E141-08	`NOT NULL` inferred on `PRIMARY KEY`	YES	
E141-10	Names in a foreign key can be specified in any order	YES	Foreign keys can be declared but are not enforced in WarehousePG
E151	Transaction support	YES	
E151-01	`COMMIT` statement	YES	
E151-02	`ROLLBACK` statement	YES	
E152	Basic SET TRANSACTION statement	YES	
E152-01	`ISOLATION LEVEL SERIALIZABLE` clause	NO	Can be declared but is treated as a synonym for `REPEATABLE READ`
E152-02	`READ ONLY` and `READ WRITE` clauses	YES	
E153	Updatable queries with subqueries	NO	
E161	SQL comments using leading double minus	YES	

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ID	Feature	Supported	Comments
E171	SQLSTATE support	YES	
E182	Module language	NO	
F021	Basic information schema	YES	
F021-01	`COLUMNS` view	YES	
F021-02	`TABLES` view	YES	
F021-03	`VIEWS` view	YES	
F021-04	`TABLE_CONSTRAINTS` view	YES	
F021-05	`REFERENTIAL_CONSTRAINTS` view	YES	
F021-06	`CHECK_CONSTRAINTS` view	YES	
F031	Basic schema manipulation	YES	
F031-01	`CREATE TABLE` statement to create persistent base tables	YES	
F031-02	`CREATE VIEW` statement	YES	
F031-03	`GRANT` statement	YES	
F031-04	`ALTER TABLE` statement: `ADD COLUMN` clause	YES	
F031-13	`DROP TABLE` statement: `RESTRICT` clause	YES	
F031-16	`DROP VIEW` statement: `RESTRICT` clause	YES	
F031-19	`REVOKE` statement: `RESTRICT` clause	YES	
F032	`CASCADE` drop behavior	YES	
F033	`ALTER TABLE` statement: `DROP COLUMN` clause	YES	
F034	Extended REVOKE statement	YES	
F034-01	`REVOKE` statement performed by other than the owner of a schema object	YES	
F034-02	`REVOKE` statement: `GRANT OPTION FOR` clause	YES	
F034-03	`REVOKE` statement to revoke a privilege that the grantee has `WITH GRANT OPTION`	YES	
F041	Basic joined table	YES	
F041-01	Inner join (but not necessarily the `INNER` keyword)	YES	
F041-02	`INNER` keyword	YES	
F041-03	`LEFT OUTER JOIN`	YES	
F041-04	`RIGHT OUTER JOIN`	YES	
F041-05	Outer joins can be nested	YES	
F041-07	The inner table in a left or right outer join can also be used in an inner join	YES	
F041-08	All comparison operators are supported (rather than just `=`)	YES	
F051	Basic date and time	YES	
F051-01	`DATE` data type (including support of `DATE` literal)	YES	
F051-02	`TIME` data type (including support of `TIME` literal) with fractional seconds precision of at least 0	YES	
F051-03	`TIMESTAMP` data type (including support of `TIMESTAMP` literal) with fractional seconds precision of at least 0 and 6	YES	
F051-04	Comparison predicate on `DATE`, `TIME`, and `TIMESTAMP` data types	YES	
F051-05	Explicit `CAST` between datetime types and character string types	YES	
F051-06	`CURRENT_DATE`	YES	
F051-07	`LOCALTIME`	YES	
F051-08	`LOCALTIMESTAMP`	YES	
F052	Intervals and datetime arithmetic	YES	
F053	`OVERLAPS` predicate	YES	
F081	`UNION` and `EXCEPT` in views	YES	
F111	Isolation levels other than SERIALIZABLE	YES	
F111-01	`READ UNCOMMITTED` isolation level	NO	Can be declared but is treated as a synonym for `READ COMMITTED`

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ID	Feature	Supported	Comments
F111-02	`READ COMMITTED` isolation level	YES	
F111-03	`REPEATABLE READ` isolation level	YES	
F121	Basic diagnostics management	NO	
F122	Enhanced diagnostics management	NO	
F123	All diagnostics	NO	
F131-	Grouped operations	YES	
F131-01	`WHERE`, `GROUP BY`, and `HAVING` clauses supported in queries with grouped views	YES	
F131-02	Multiple tables supported in queries with grouped views	YES	
F131-03	Set functions supported in queries with grouped views	YES	
F131-04	Subqueries with `GROUP BY` and `HAVING` clauses and grouped views	YES	
F131-05	Single row `SELECT` with `GROUP BY` and `HAVING` clauses and grouped views	YES	
F171	Multiple schemas per user	YES	
F181	Multiple module support	NO	
F191	Referential delete actions	NO	
F200	`TRUNCATE TABLE` statement	YES	
F201	`CAST` function	YES	
F202	`TRUNCATE TABLE`: identity column restart option	YES	
F221	Explicit defaults	YES	
F222	`INSERT` statement: `DEFAULT VALUES` clause	YES	
F231	Privilege tables	YES	
F231-01	`TABLE_PRIVILEGES` view	YES	
F231-02	`COLUMN_PRIVILEGES` view	YES	
F231-03	`USAGE_PRIVILEGES` view	YES	
F251	Domain support		
F261	CASE expression	YES	
F261-01	Simple `CASE`	YES	
F261-02	Searched `CASE`	YES	
F261-03	`NULLIF`	YES	
F261-04	`COALESCE`	YES	
F262	Extended `CASE` expression	NO	
F263	Comma-separated predicates in simple `CASE` expression	NO	
F271	Compound character literals	YES	
F281	`LIKE` enhancements	YES	
F291	`UNIQUE` predicate	NO	
F301	`CORRESPONDING` in query expressions	NO	
F302	INTERSECT table operator	YES	
F302-01	`INTERSECT DISTINCT` table operator	YES	
F302-02	`INTERSECT ALL` table operator	YES	
F304	`EXCEPT ALL` table operator		
F311	Schema definition statement	YES	Partial sub-feature support
F311-01	`CREATE SCHEMA`	YES	
F311-02	`CREATE TABLE` for persistent base tables	YES	
F311-03	`CREATE VIEW`	YES	
F311-04	`CREATE VIEW: WITH CHECK OPTION`	NO	
F311-05	`GRANT` statement	YES	
F312	`MERGE` statement	NO	consider `INSERT ... ON CONFLICT DO UPDATE`
F313	Enhanced `MERGE` statement	NO	
F321	User authorization	YES	
F341	Usage Tables	NO	
F361	Subprogram support	YES	
F381	Extended schema manipulation	YES	
F381-01	`ALTER TABLE` statement: `ALTER COLUMN` clause		Some limitations on altering distribution key columns

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ID	Feature	Supported	Comments
F381-02	`ALTER TABLE` statement: `ADD CONSTRAINT` clause		
F381-03	`ALTER TABLE` statement: `DROP CONSTRAINT` clause		
F382	Alter column data type	YES	Some limitations on altering distribution key columns
F384	Drop identity property clause	YES	
F386	Set identity column generation clause	YES	
F391	Long identifiers	YES	
F392	Unicode escapes in identifiers	NO	
F393	Unicode escapes in literals	NO	
F394	Optional normal form specification	NO	
F401	Extended joined table	YES	
F401-01	`NATURAL JOIN`	YES	
F401-02	`FULL OUTER JOIN`	YES	
F401-04	`CROSS JOIN`	YES	
F402	Named column joins for LOBs, arrays, and multisets	NO	
F403	Partitioned joined tables	NO	
F411	Time zone specification	YES	Differences regarding literal interpretation
F421	National character	YES	
F431	Read-only scrollable cursors	YES	Forward scrolling only
01	`FETCH` with explicit `NEXT`	YES	
02	`FETCH FIRST`	NO	
03	`FETCH LAST`	YES	
04	`FETCH PRIOR`	NO	
05	`FETCH ABSOLUTE`	NO	
06	`FETCH RELATIVE`	NO	
F441	Extended set function support	YES	
F442	Mixed column references in set functions	YES	
F451	Character set definition	NO	
F461	Named character sets	NO	
F471	Scalar subquery values	YES	
F481	Expanded `NULL` predicate	YES	
F491	Constraint management	YES	
F501	Features and conformance views	YES	
F501-01	`SQL_FEATURES` view	YES	
F501-02	`SQL_SIZING` view	YES	
F501-03	`SQL_LANGUAGES` view	YES	
F502	Enhanced documentation tables	YES	
F502-01	`SQL_SIZING_PROFILES` view	YES	
F502-02	`SQL_IMPLEMENTATION_INFO` view	YES	
F502-03	`SQL_PACKAGES` view	YES	
F521	Assertions	NO	
F531	Temporary tables	YES	Non-standard form
F555	Enhanced seconds precision	YES	
F561	Full value expressions	YES	
F571	Truth value tests	YES	
F591	Derived tables	YES	
F611	Indicator data types	YES	
F641	Row and table constructors	NO	
F651	Catalog name qualifiers	YES	
F661	Simple tables	NO	
F671	Subqueries in `CHECK`	NO	Intentionally omitted
F672	Retrospective check constraints	YES	
F690	Collation support	NO	
F692	Enhanced collation support	NO	
F693	SQL-session and client module collations	NO	
F695	Translation support	NO	
F696	Additional translation documentation	NO	
F701	Referential update actions	NO	
F711	`ALTER` domain	YES	
F721	Deferrable constraints	NO	

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ID	Feature	Supported	Comments
F731	`INSERT` column privileges	YES	
F741	Referential `MATCH` types	NO	No partial match
F751	View `CHECK` enhancements	NO	
F761	Session management	YES	
F762	`CURRENT_CATALOG`	NO	
F763	`CURRENT_SCHEMA`	NO	
F771	Connection management	YES	
F781	Self-referencing operations	YES	
F791	Insensitive cursors	YES	
F801	Full set function	YES	
F812	Basic flagging	NO	
F813	Extended flagging	NO	
F831	Full cursor update	NO	
F841	`LIKE_REGEX` predicate	NO	Non-standard syntax for regex
F842	`OCCURENCES_REGEX` function	NO	
F843	`POSITION_REGEX` function	NO	
F844	`SUBSTRING_REGEX` function	NO	
F845	`TRANSLATE_REGEX` function	NO	
F846	Octet support in regular expression operators	NO	
F847	Nonconstant regular expressions	NO	
F850	Top-level `ORDER BY` clause in *query expression*	YES	
F851	Top-level `ORDER BY` clause in subqueries	NO	
F852	Top-level `ORDER BY` clause in views	NO	
F855	Nested `ORDER BY` clause in *query expression*	NO	
F856	Nested `FETCH FIRST` clause in *query expression*	NO	
F857	Top-level `FETCH FIRST` clause in *query expression*	NO	
F858	`FETCH FIRST` clause in subqueries	NO	
F859	Top-level `FETCH FIRST` clause in views	NO	
F860	`FETCH FIRST ROW` *count* in `FETCH FIRST` clause	NO	
F861	Top-level `RESULT OFFSET` clause in *query expression*	NO	
F862	`RESULT OFFSET` clause in subqueries	NO	
F863	Nested `RESULT OFFSET` clause in *query expression*	NO	
F864	Top-level `RESULT OFFSET` clause in views	NO	
F865	`OFFSET ROW` *count* in `RESULT OFFSET` clause	NO	
S011	Distinct data types	NO	
S023	Basic structured types	NO	
S024	Enhanced structured types	NO	
S025	Final structured types	NO	
S026	Self-referencing structured types	NO	
S027	Create method by specific method name	NO	
S028	Permutable UDT options list	NO	
S041	Basic reference types	NO	
S043	Enhanced reference types	NO	
S051	Create table of type	NO	
S071	SQL paths in function and type name resolution	YES	
S091	Basic array support	NO	WarehousePG has arrays, but is not fully standards compliant
S091-01	Arrays of built-in data types	NO	Partially compliant
S091-02	Arrays of distinct types	NO	
S091-03	Array expressions	NO	
S092	Arrays of user-defined types	NO	
S094	Arrays of reference types	NO	
S095	Array constructors by query	NO	
S096	Optional array bounds	NO	
S097	Array element assignment	NO	
S098	`array_agg`	Partially	Supported: Using `array_agg` without a window specification, for example: `SELECT array_agg(x) FROM ...`, `SELECT array_agg (x order by y) FROM ...` Not supported: Using `array_agg` as an aggregate derived window function, for example: `SELECT array_agg(x) over (ORDER BY y) FROM ...`, `SELECT array_agg(x order by y) over (PARTITION BY z) FROM ...`, `SELECT array_agg(x order by y) over (ORDER BY z) FROM ...`
S111	`ONLY` in query expressions	YES	
S151	Type predicate	NO	

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ID	Feature	Supported	Comments
S161	Subtype treatment	NO	
S162	Subtype treatment for references	NO	
S201	SQL-invoked routines on arrays	NO	Functions can be passed WarehousePG cluster types
S202	SQL-invoked routines on multisets	NO	
S211	User-defined cast functions	YES	
S231	Structured type locators	NO	
S232	Array locators	NO	
S233	Multiset locators	NO	
S241	Transform functions	NO	
S242	Alter transform statement	NO	
S251	User-defined orderings	NO	
S261	Specific type method	NO	
S271	Basic multiset support	NO	
S272	Multisets of user-defined types	NO	
S274	Multisets of reference types	NO	
S275	Advanced multiset support	NO	
S281	Nested collection types	NO	
S291	Unique constraint on entire row	NO	
S301	Enhanced `UNNEST`	NO	
S401	Distinct types based on array types	NO	
S402	Distinct types based on distinct types	NO	
S403	`MAX_CARDINALITY`	NO	
S404	`TRIM_ARRAY`	NO	
T011	Timestamp in Information Schema	NO	
T021	`BINARY` and `VARBINARY` data types	NO	
T022	Advanced support for `BINARY` and `VARBINARY` data types	NO	
T023	Compound binary literal	NO	
T024	Spaces in binary literals	NO	
T031	`BOOLEAN` data type	YES	
T041	Basic `LOB` data type support	NO	
T042	Extended `LOB` data type support	NO	
T043	Multiplier T	NO	
T044	Multiplier P	NO	
T051	Row types	NO	
T052	`MAX` and `MIN` for row types	NO	
T053	Explicit aliases for all-fields reference	NO	
T061	UCS support	NO	
T071	`BIGINT` data type	YES	
T101	Enhanced nullability determiniation	NO	
T111	Updatable joins, unions, and columns	NO	
T121	`WITH` (excluding `RECURSIVE`) in query expression	NO	
T122	`WITH` (excluding `RECURSIVE`) in subquery	NO	
T131	Recursive query	NO	
T132	Recursive query in subquery	NO	
T141	`SIMILAR` predicate	YES	
T151	`DISTINCT` predicate	YES	
T152	`DISTINCT` predicate with negation	NO	
T171	`LIKE` clause in table definition	YES	
T172	`AS` subquery clause in table definition	YES	
T173	Extended `LIKE` clause in table definition	YES	
T174	Identity columns	YES	
T175	Generated columns	NO	
T176	Sequence generator support	NO	
T177	Sequence generator support: simple restart option	NO	
T178	Identity columns: simple restart option	YES	
T191	Referential action `RESTRICT`	NO	
T201	Comparable data types for referential constraints	NO	
T211	Basic trigger capability	NO	
T211-01	Triggers activated on `UPDATE`, `INSERT`, or `DELETE` of one base table	NO	
T211-02	`BEFORE` triggers	NO	
T211-03	`AFTER` triggers	NO	
T211-04	`FOR EACH ROW` triggers	NO	
T211-05	Ability to specify a search condition that must be true before the trigger is invoked	NO	

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ID	Feature	Supported	Comments
T211-06	Support for run-time rules for the interaction of triggers and constraints	NO	
T211-07	`TRIGGER` privilege	YES	
T211-08	Multiple triggers for the same event are run in the order in which they were created in the catalog	NO	Intentionally omitted
T212	Enhanced trigger capability	NO	
T213	`INSTEAD OF` triggers	NO	
T231	Sensitive cursors	YES	
T241	`START TRANSACTION` statement	YES	
T251	`SET TRANSACTION` statement: `LOCAL` option	NO	
T261	Chained transactions	NO	
T271	Savepoints	YES	
T272	Enhanced savepoint management	NO	
T281	`SELECT` privilege with column granularity	YES	
T285	Enhanced derived column names	NO	
T301	Functional dependencies	NO	
T312	OVERLAY function	YES	
T321	Basic SQL-invoked routines	NO	Partial support
T321-01	User-defined functions with no overloading	YES	
T321-02	User-defined stored procedures with no overloading	NO	
T321-03	Function invocation	YES	
T321-04	CALL statement	NO	
T321-05	RETURN statement	NO	
T321-06	ROUTINES view	YES	
T321-07	PARAMETERS view	YES	
T322	Overloading of SQL-invoked functions and procedures	YES	
T323	Explicit security for external routines	YES	
T324	Explicit security for SQL routines	NO	
T325	Qualified SQL parameter references	NO	
T326	Table functions	NO	
T331	Basic roles	NO	
T332	Extended roles	NO	
T351	Bracketed SQL comments (`/*...*/` comments)	YES	
T431	Extended grouping capabilities	NO	
T432	Nested and concatenated `GROUPING SETS`	NO	
T433	Multiargument `GROUPING` function	NO	
T434	`GROUP BY DISTINCT`	NO	
T441	`ABS` and `MOD` functions	YES	
T461	Symmetric `BETWEEN` predicate	YES	
T471	Result sets return value	NO	
T491	`LATERAL` derived table	NO	
T501	Enhanced `EXISTS` predicate	NO	
T511	Transaction counts	NO	
T541	Updatable table references	NO	
T561	Holdable locators	NO	
T571	Array-returning external SQL-invoked functions	NO	
T572	Multiset-returning external SQL-invoked functions	NO	
T581	Regular expression substring function	YES	
T591	`UNIQUE` constraints of possibly null columns	YES	
T601	Local cursor references	NO	
T611	Elementary OLAP operations	YES	
T612	Advanced OLAP operations	NO	Partially supported
T613	Sampling	NO	
T614	`NTILE` function	YES	
T615	`LEAD` and `LAG` functions	YES	
T616	Null treatment option for `LEAD` and `LAG` functions	NO	
T617	`FIRST_VALUE` and `LAST_VALUE` function	YES	
T618	`NTH_VALUE`	NO	Function exists in WarehousePG but not all options are supported
T621	Enhanced numeric functions	YES	
T631	N predicate with one list element	NO	
T641	Multiple column assignment	NO	Some syntax variants supported
T651	SQL-schema statements in SQL routines	NO	

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ID	Feature	Supported	Comments
T652	SQL-dynamic statements in SQL routines	NO	
T653	SQL-schema statements in external routines	NO	
T654	SQL-dynamic statements in external routines	NO	
T655	Cyclically dependent routines	NO	
M001	Datalinks	NO	
M002	Datalinks via SQL/CLI	NO	
M003	Datalinks via Embedded SQL	NO	
M004	Foreign data support	NO	
M005	Foreign schema support	NO	
M006	GetSQLString routine	NO	
M007	TransmitRequest	NO	
M009	GetOpts and GetStatistics routines	NO	
M010	Foreign data wrapper support	NO	
M011	Datalinks via Ada	NO	
M012	Datalinks via C	NO	
M013	Datalinks via COBOL	NO	
M014	Datalinks via Fortran	NO	
M015	Datalinks via M	NO	
M016	Datalinks via Pascal	NO	
M017	Datalinks via PL/I	NO	
M018	Foreign data wrapper interface routines in Ada	NO	
M019	Foreign data wrapper interface routines in C	NO	
M020	Foreign data wrapper interface routines in COBOL	NO	
M021	Foreign data wrapper interface routines in Fortran	NO	
M022	Foreign data wrapper interface routines in MUMPS	NO	
M023	Foreign data wrapper interface routines in Pascal	NO	
M024	Foreign data wrapper interface routines in PL/I	NO	
M030	SQL-server foreign data support	NO	
M031	Foreign data wrapper general routines	NO	
X010	XML type	YES	
X011	Arrays of XML type	YES	
X012	Multisets of XML type	NO	
X013	Distinct types of XML type	NO	
X014	Attributes of XML type	NO	
X015	Fields of XML type	NO	
X016	Persistent XML values	YES	
X020	XMLConcat	YES	xmlconcat2() supported
X025	XMLCast	NO	
X030	XMLDocument	NO	
X031	XMLElement	YES	
X032	XMLForest	YES	
X034	XMLAgg	YES	
X035	XMLAgg: ORDER BY option	YES	
X036	XMLComment	YES	
X037	XMLPI	YES	
X038	XMLText	NO	
X040	Basic table mapping	NO	
X041	Basic table mapping: nulls absent	NO	
X042	Basic table mapping: null as nil	NO	
X043	Basic table mapping: table as forest	NO	
X044	Basic table mapping: table as element	NO	
X045	Basic table mapping: with target namespace	NO	
X046	Basic table mapping: data mapping	NO	
X047	Basic table mapping: metadata mapping	NO	
X048	Basic table mapping: base64 encoding of binary strings	NO	
X049	Basic table mapping: hex encoding of binary strings	NO	
X051	Advanced table mapping: nulls absent	NO	
X052	Advanced table mapping: null as nil	NO	
X053	Advanced table mapping: table as forest	NO	
X054	Advanced table mapping: table as element	NO	
X055	Advanced table mapping: target namespace	NO	
X056	Advanced table mapping: data mapping	NO	
X057	Advanced table mapping: metadata mapping	NO	
X058	Advanced table mapping: base64 encoding of binary strings	NO	
X059	Advanced table mapping: hex encoding of binary strings	NO	
X060	XMLParse: Character string input and CONTENT option	YES	
X061	XMLParse: Character string input and DOCUMENT option	YES	
X065	XMLParse: BLOB input and CONTENT option	NO	

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ID	Feature	Supported	Comments
X066	XMLParse: BLOB input and DOCUMENT option	NO	
X068	XMLSerialize: BOM	NO	
X069	XMLSerialize: INDENT	NO	
X070	XMLSerialize: Character string serialization and CONTENT option	YES	
X071	XMLSerialize: Character string serialization and DOCUMENT option	YES	
X072	XMLSerialize: Character string serialization	YES	
X073	XMLSerialize: BLOB serialization and CONTENT option	NO	
X074	XMLSerialize: BLOB serialization and DOCUMENT option	NO	
X075	XMLSerialize: BLOB serialization	NO	
X076	XMLSerialize: VERSION	NO	
X077	XMLSerialize: explicit ENCODING option	NO	
X078	XMLSerialize: explicit XML declaration	NO	
X080	Namespaces in XML publishing	NO	
X081	Query-level XML namespace declarations	NO	
X082	XML namespace declarations in DML	NO	
X083	XML namespace declarations in DDL	NO	
X084	XML namespace declarations in compound statements	NO	
X085	Predefined namespace prefixes	NO	
X086	XML namespace declarations in XMLTable	NO	
X090	XML document predicate	NO	xml_is_well_formed_document() supported
X091	XML content predicate	NO	xml_is_well_formed_content() supported
X096	XMLExists	NO	xmlexists() supported
X100	Host language support for XML: CONTENT option	NO	
X101	Host language support for XML: DOCUMENT option	NO	
X110	Host language support for XML: VARCHAR mapping	NO	
X111	Host language support for XML: CLOB mapping	NO	
X112	Host language support for XML: BLOB mapping	NO	
X113	Host language support for XML: STRIP WHITESPACE option	YES	
X114	Host language support for XML: PRESERVE WHITESPACE option	YES	
X120	XML parameters in SQL routines	YES	
X121	XML parameters in external routines	YES	
X131	Query-level XMLBINARY clause	NO	
X132	XMLBINARY clause in DML	NO	
X133	XMLBINARY clause in DDL	NO	
X134	XMLBINARY clause in compound statements	NO	
X135	XMLBINARY clause in subqueries	NO	
X141	IS VALID predicate: data-driven case	NO	
X142	IS VALID predicate: ACCORDING TO clause	NO	
X143	IS VALID predicate: ELEMENT clause	NO	
X144	IS VALID predicate: schema location	NO	
X145	IS VALID predicate outside check constraints	NO	
X151	IS VALID predicate with DOCUMENT option	NO	
X152	IS VALID predicate with CONTENT option	NO	
X153	IS VALID predicate with SEQUENCE option	NO	
X155	IS VALID predicate: NAMESPACE without ELEMENT clause	NO	
X157	IS VALID predicate: NO NAMESPACE with ELEMENT clause	NO	
X160	Basic Information Schema for registered XML Schemas	NO	
X161	Advanced Information Schema for registered XML Schemas	NO	
X170	XML null handling options	NO	
X171	NIL ON NO CONTENT option	NO	
X181	XML(DOCUMENT (UNTYPED)) type	NO	
X182	XML(DOCUMENT (ANY)) type	NO	
X190	XML(SEQUENCE) type	NO	
X191	XML(DOCUMENT (XMLSCHEMA)) type	NO	
X192	XML(CONTENT (XMLSCHEMA)) type	NO	
X200	XMLQuery	NO	
X201	XMLQuery: RETURNING CONTENT	NO	
X202	XMLQuery: RETURNING SEQUENCE	NO	
X203	XMLQuery: passing a context item	NO	
X204	XMLQuery: initializing an XQuery variable	NO	
X205	XMLQuery: EMPTY ON EMPTY option	NO	
X206	XMLQuery: NULL ON EMPTY option	NO	
X211	XML 1.1 support	NO	
X221	XML passing mechanism BY VALUE	NO	
X222	XML passing mechanism BY REF	NO	
X231	XML(CONTENT (UNTYPED)) type	NO	
X232	XML(CONTENT (ANY)) type	NO	
X241	RETURNING CONTENT in XML publishing	NO	

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ID	Feature	Supported	Comments
X242	RETURNING SEQUENCE in XML publishing	NO	
X251	Persistent XML values of XML(DOCUMENT (UNTYPED)) type	NO	
X252	Persistent XML values of XML(DOCUMENT (ANY)) type	NO	
X253	Persistent XML values of XML(CONTENT (UNTYPED)) type	NO	
X254	Persistent XML values of XML(CONTENT (ANY)) type	NO	
X255	Persistent XML values of XML(SEQUENCE) type	NO	
X256	Persistent XML values of XML(DOCUMENT (XMLSCHEMA)) type	NO	
X257	Persistent XML values of XML(CONTENT (XMLSCHEMA) type	NO	
X260	XML type: ELEMENT clause	NO	
X261	XML type: NAMESPACE without ELEMENT clause	NO	
X263	XML type: NO NAMESPACE with ELEMENT clause	NO	
X264	XML type: schema location	NO	
X271	XMLValidate: data-driven case	NO	
X272	XMLValidate: ACCORDING TO clause	NO	
X273	XMLValidate: ELEMENT clause	NO	
X274	XMLValidate: schema location	NO	
X281	XMLValidate: with DOCUMENT option	NO	
X282	XMLValidate with CONTENT option	NO	
X283	XMLValidate with SEQUENCE option	NO	
X284	XMLValidate NAMESPACE without ELEMENT clause	NO	
X286	XMLValidate: NO NAMESPACE with ELEMENT clause	NO	
X300	XMLTable	NO	
X301	XMLTable: derived column list option	NO	
X302	XMLTable: ordinality column option	NO	
X303	XMLTable: column default option	NO	
X304	XMLTable: passing a context item	NO	
X305	XMLTable: initializing an XQuery variable	NO	
X400	Name and identifier mapping	NO	

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7.11 Server Configuration Parameter Changes from WarehousePG 6 to WarehousePG 7

WarehousePG 7 includes new server configuration parameters, and removes or updates the default values of certain server configuration parameters as described below.

New Parameters

The following new server configuration parameters are available in WarehousePG 7:

- `allow_in_place_tablespaces`
- `archive_cleanup_command`
- `backend_flush_after`
- `bgwriter_flush_after`
- `checkpoint_flush_after`
- `cluster_name`
- `data_directory_mode`
- `debug_deadlocks`
- `default_table_access_method`
- `dtx_phase2_retry_second`
- `enable_gathermerge`
- `enable_groupingsets_hash_disk`
- `enable_hashagg_disk`
- `enable_parallel_append`
- `enable_parallel_hash`
- `enable_partition_pruning`
- `enable_partitionwise_aggregate`
- `enable_partitionwise_join`
- `force_parallel_mode`
- `gin_pending_list_limit`
- `gp_autovacuum_scope`
- `gp_detect_data_correctness`
- `gp_explain_jit`
- `gp_force_random_redistribution`
- `gp_gxid_prefetch_num`
- `gp_max_alloc_size`
- `gp_pause_on_restore_point_replay`
- `gp_quicklz_fallback`
- `gp_resgroup_memory_query_fixed_mem`
- `gp_resource_group_bypass_direct_dispatch`
- `gp_workfile_compression_overhead_limit`
- `idle_in_transaction_session_timeout`
- `jit`
- `jit_above_cost`
- `jit_debugging_support`
- `jit_dump_bitcode`
- `jit_expressions`
- `jit_inline_above_cost`
- `jit_optimize_above_cost`
- `jit_profiling_support`
- `jit_provider`
- `jit_tuple_deforming`
- `log_btree_build_stats`
- `log_replication_commands`
- `log_statement_sample_rate`
- `log_transaction_sample_rate`
- `max_logical_replication_workers`
- `max_parallel_maintenance_workers`
- `max_parallel_workers`
- `max_parallel_workers_per_gather`
- `max_pred_locks_per_page`
- `max_pred_locks_per_relation`
- `max_sync_workers_per_subscription`
- `max_wal_size`
- `min_parallel_index_scan_size`
- `min_parallel_table_scan_size`
- `min_wal_size`
- `old_snapshot_threshold`
- `operator_precedence_warning`
- `optimize_bounded_sort`
- `optimizer_enable_coordinator_only_queries`
- `optimizer_enable_dynamicindexonlyscan`
- `optimizer_enable_foreign_table`
- `optimizer_enable_motions_coordinatoronly_queries`
- `optimizer_enable_nljoin`
- `optimizer_enable_push_join_below_union_all`
- `optimizer_jit_above_cost`
- `optimizer_jit_inline_above_cost`
- `optimizer_jit_optimize_above_cost`
- `parallel_leader_participation`
- `parallel_setup_cost`
- `parallel_tuple_cost`
- `primary_conninfo`
- `primary_slot_name`
- `promote_trigger_file`
- `recovery_end_command`
- `recovery_min_apply_delay`
- `recovery_target`
- `recovery_target_action`
- `recovery_target_inclusive`
- `recovery_target_lsn`
- `recovery_target_name`

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- recovery_target_time
- recovery_target_timeline
- recovery_target_xid
- restore_command
- row_security
- shared_memory_type
- ssl_dh_params_file
- ssl_library
- ssl_max_protocol_version
- ssl_min_protocol_version
- ssl_passphrase_command
- ssl_passphrase_command_supports_reload
- ssl_renegotiation_limit
- syslog_sequence_numbers
- syslog_split_messages
- tcp_user_timeout
- trace_lock_oidmin
- trace_locks
- trace_lock_table
- trace_lwlocks
- trace_syncscan
- trace_userlocks
- track_commit_timestamp
- track_wal_io_timing
- vacuum_cleanup_index_scale_factor
- wal_compression
- wal_consistency_checking
- wal_debug
- wal_init_zero
- wal_keep_size
- wal_recycle
- wal_retrieve_retry_interval
- wal_writer_flush_after

Removed Parameters

The following server configuration parameters are removed in WarehousePG 7:

- checkpoint_segments
- debug_latch
- dev_opt_unsafe_truncate_in_subtransaction
- dtx_phase2_retry_count
- enable_implicit_timeformat_YYYYMMDDHH24MISS
- gp_add_column_inherits_table_setting
- gp_allow_rename_relation_without_lock
- gp_count_host_segments_using_address
- gp_eager_agg_distinct_pruning
- gp_eager_one_phase_agg
- gp_eager_preunique
- gp_enable_exchange_default_partition
- gp_enable_gpperfmon
- gp_enable_mk_sort
- gp_enable_motion_mk_sort
- gp_enable_sort_distinct
- gp_gpperfmon_send_interval
- gp_hashagg_default_nbatches
- gp_hashagg_groups_per_bucket
- gp_hashagg_streambottom
- gp_ignore_window_exclude
- gp_indexcheck_vacuum
- gp_keep_all_xlog
- gp_log_resqueue_priority_sleep_time
- gp_max_partition_level
- gp_mk_sort_check
- gp_partitioning_dynamic_selection_log
- gpperfmon_log_alert_level
- gpperfmon_port
- gp_perfmon_print_packet_info
- gp_perfmon_segment_interval
- gp_resgroup_print_operator_memory_limits
- gp_resource_group_cpu_ceiling_enforcement
- gp_resource_group_enable_recalculate_query_mem
- gp_resource_group_memory_limit
- gp_safefswritesize
- gp_sort_flags
- gp_sort_max_distinct
- gp_use_synchronize_seqscans_catalog_vacuum_full
- memory_spill_ratio
- optimizer_analyze_enable_merge_of_leaf_stats
- optimizer_enable_dml_triggers
- optimizer_enable_partial_index
- optimizer_prune_unused_columns
- password_hash_algorithm
- test_print_prefetch_joinqual
- wal_keep_segments

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Changed Parameters

These server configuration parameters are changed in WarehousePG 7:

- The server configuration paramater `optimizer_enable_orderedagg` has a new default value of `on`.
- The server configuration parameter `vacuum_cost_page_miss` has a new default value of 2.
- The default value for the server configuration parameter `gp_interconnect_address_type` changed from `wildcard` to `unicast`.
- The `wal_keep_segments` server configuration parameter has been replaced by the `wal_keep_size` parameter.
- The `autovacuum` server configuration parameter is now enabled for all databases by default, rather than just for the `template0` and `template1` databases.
- The `gp_autostats_mode` server configuration parameter default value has been changed to `none`.
- The `gp_default_storage_options` parameter no longer supports the `appendonly` and `appendoptimized` keywords. Use the `default_table_access_method` parameter instead.

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7.12 Features and Objects Removed in WarehousePG 7

WarehousePG 7 removes several database features and objects. These changes can potentially affect successfully upgrading from one major version to another. Review this list of removed features and objects before upgrading from WarehousePG 6 to WarehousePG 7.

Removed Features

The following features have been removed in WarehousePG 7:

- Support for Quicklz compression. To avoid breaking applications that use Quicklz, set the `gp_quicklz_fallback` server configuration parameter to `true`.
- The `--skip_root_stats` option of the `analyzedb` utility. `analyzedb` populates root statistics required by the optimizer by default.
- The WarehousePG R Client.
- WarehousePG MapReduce.
- The `ARRAY_NAME` variable. It is no longer used by WarehousePG.
- The PL/Container 3.0 Beta extension. Instead, use the regular PL/Container extension.
- The `gp_percentil_agg` extension. This is not part of the core WarehousePG product.
- The `createlang` and `droplang` utilties. Instead, use `CREATE EXTENSION` and `DROP EXTENSION` directly.
- Support for python2 and the `plpythonu` extension.

Removed Objects

This section summarizes objects removed in WarehousePG 7.

- Removed Tables and Views
- Removed Columns
- Removed Functions and Procedures
- Removed Types, Domains, and Composite Types
- Removed Operators

Removed Tables and Views

The following list includes the tables and views removed in WarehousePG 7.

- gp_toolkit.gp_size_of_partition_and_indexes_disk
- gp_toolkit.__gp_user_data_tables
- pg_catalog.pg_partition
- pg_catalog.pg_partition_columns
- pg_catalog.pg_partition_encoding
- pg_catalog.pg_partition_rule
- pg_catalog.pg_partitions
- pg_catalog.pg_partition_templates
- pg_catalog.pg_stat_partition_operations

Removed Columns

The following list includes the columns removed in WarehousePG 7.

- gp_toolkit.gp_locks_on_resqueue.lorwaiting
- gp_toolkit.gp_resgroup_config.cpu_rate_limit
- gp_toolkit.gp_resgroup_config.memory_auditor
- gp_toolkit.gp_resgroup_config.memory_shared_quota
- gp_toolkit.gp_resgroup_config.memory_spill_ratio
- gp_toolkit.gp_resgroup_status.cpu_usage
- gp_toolkit.gp_resgroup_status.memory_usage
- gp_toolkit.gp_resgroup_status_per_host.cpu
- gp_toolkit.gp_resgroup_status_per_host.memory_available
- gp_toolkit.gp_resgroup_status_per_host.memory_quota_available
- gp_toolkit.gp_resgroup_status_per_host.memory_quota_used
- gp_toolkit.gp_resgroup_status_per_host.memory_shared_available
- gp_toolkit.gp_resgroup_status_per_host.memory_shared_used
- gp_toolkit.gp_resgroup_status_per_host.memory_used
- gp_toolkit.gp_resgroup_status_per_host.rsgname
- gp_toolkit.gp_resgroup_status_per_segment.cpu
- gp_toolkit.gp_resgroup_status_per_segment.hostname
- gp_toolkit.gp_resgroup_status_per_segment.memory_available
- gp_toolkit.gp_resgroup_status_per_segment.memory_quota_available
- gp_toolkit.gp_resgroup_status_per_segment.memory_quota_used
- gp_toolkit.gp_resgroup_status_per_segment.memory_shared_available
- gp_toolkit.gp_resgroup_status_per_segment.memory_shared_used
- gp_toolkit.gp_resgroup_status_per_segment.memory_used
- gp_toolkit.gp_resgroup_status_per_segment.rsgname
- gp_toolkit.gp_resgroup_status.rsgname
- gp_toolkit.__gp_user_tables.autrelstorage
- information_schema.routines.result_cast_character_set_name
- information_schema.routines.sql_data_access
- pg_catalog.gp_configuration_history.desc

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- pg_catalog.gp_distributed_log.distributed_id
- pg_catalog.gp_distributed_xacts.distributed_id
- pg_catalog.gp_stat_replication.flush_location
- pg_catalog.gp_stat_replication.replay_location
- pg_catalog.gp_stat_replication.sent_location
- pg_catalog.gp_stat_replication.write_location
- pg_catalog.pg_proc.protransform
- pg_catalog.pg_proc.proisagg
- pg_catalog.pg_proc.proiswindow
- pg_catalog.pg_am.ambeginscan
- pg_catalog.pg_am.ambuild
- pg_catalog.pg_am.ambuildempty
- pg_catalog.pg_am.ambulkdelete
- pg_catalog.pg_am.amcanbackward
- pg_catalog.pg_am.amcanmulticol
- pg_catalog.pg_am.amcanorder
- pg_catalog.pg_am.amcanorderbyop
- pg_catalog.pg_am.amcanreturn
- pg_catalog.pg_am.amcanunique
- pg_catalog.pg_am.amclusterable
- pg_catalog.pg_am.amcostestimate
- pg_catalog.pg_am.amendscan
- pg_catalog.pg_am.amgetbitmap
- pg_catalog.pg_am.amgettuple
- pg_catalog.pg_am.aminsert
- pg_catalog.pg_am.amkeytype
- pg_catalog.pg_am.ammarkpos
- pg_catalog.pg_am.amoptionalkey
- pg_catalog.pg_am.amoptions
- pg_catalog.pg_am.ampredlocks
- pg_catalog.pg_am.amrescan
- pg_catalog.pg_am.amrestrpos
- pg_catalog.pg_am.amsearcharray
- pg_catalog.pg_am.amsearchnulls
- pg_catalog.pg_am.amstorage
- pg_catalog.pg_am.amstrategies
- pg_catalog.pg_am.amsupport
- pg_catalog.pg_am.amvacuumcleanup
- pg_catalog.pg_appendonly.blkdiridxid
- pg_catalog.pg_appendonly.blocksize
- pg_catalog.pg_appendonly.checksum
- pg_catalog.pg_appendonly.columnstore
- pg_catalog.pg_appendonly.compresslevel
- pg_catalog.pg_appendonly.compresstype
- pg_catalog.pg_appendonly.safefswritesize
- pg_catalog.pg_appendonly.visimapidxid
- pg_catalog.pg_attrdef.adsrc
- pg_catalog.pg_authid.rolcatupdate
- pg_catalog.pg_class.relhasoids
- pg_catalog.pg_class.relhaspkey
- pg_catalog.pg_class.relstorage
- pg_catalog.pg_constraint.consrc

Removed Functions

The following list includes the functions removed in WarehousePG 7.

- pg_catalog.abstime
- pg_catalog.abstimeeq
- pg_catalog.abstimege
- pg_catalog.abstimegt
- pg_catalog.abstimein
- pg_catalog.abstimele
- pg_catalog.abstimelt
- pg_catalog.abstimene
- pg_catalog.abstimeout
- pg_catalog.abstimerecv
- pg_catalog.abstimesend
- pg_catalog.bmbeginscan
- pg_catalog.bmbuild
- pg_catalog.bmbuildempty
- pg_catalog.bmbulkdelete
- pg_catalog.bmcostestimate
- pg_catalog.bmendscan
- pg_catalog.bmgetbitmap
- pg_catalog.bmgettuple
- pg_catalog.bminsert
- pg_catalog.bmmarkpos
- pg_catalog.bmoptions
- pg_catalog.bmrescan
- pg_catalog.bmrestrpos
- pg_catalog.bmvacuumcleanup
- pg_catalog.btabstimecmp
- pg_catalog.btbeginscan
- pg_catalog.btbuild
- pg_catalog.btbuildempty
- pg_catalog.btbulkdelete
- pg_catalog.btcanreturn
- pg_catalog.btcostestimate
- pg_catalog.btendscan
- pg_catalog.btgetbitmap
- pg_catalog.btgettuple
- pg_catalog.btinsert
- pg_catalog.btmarkpos
- pg_catalog.btoptions
- pg_catalog.btreltimecmp
- pg_catalog.btrescan
- pg_catalog.btrestrpos
- pg_catalog.bttintervalcmp
- pg_catalog.btvacuumcleanup

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- pg_catalog.cdblegacyhash_abstime
- pg_catalog.cdblegacyhash_reltime
- pg_catalog.cdblegacyhash_tinterval
- pg_catalog.ginbeginscan
- pg_catalog.ginbuild
- pg_catalog.ginbuildempty
- pg_catalog.ginbulkdelete
- pg_catalog.gincostestimate
- pg_catalog.ginendscan
- pg_catalog.gingetbitmap
- pg_catalog.gininsert
- pg_catalog.ginmarkpos
- pg_catalog.ginoptions
- pg_catalog.ginrescan
- pg_catalog.ginrestrpos
- pg_catalog.ginvacuumcleanup
- pg_catalog.gistbeginscan
- pg_catalog.gist_box_compress
- pg_catalog.gist_box_decompress
- pg_catalog.gistbuild
- pg_catalog.gistbuildempty
- pg_catalog.gistbulkdelete
- pg_catalog.gistcostestimate
- pg_catalog.gistendscan
- pg_catalog.gistgetbitmap
- pg_catalog.gistgettuple
- pg_catalog.gistinsert
- pg_catalog.gistmarkpos
- pg_catalog.gistoptions
- pg_catalog.gistrescan
- pg_catalog.gistrestrpos
- pg_catalog.gistvacuumcleanup
- pg_catalog.gp_elog
- pg_catalog.gp_fault_inject
- pg_catalog.gp_quicklz_compress
- pg_catalog.gp_quicklz_constructor
- pg_catalog.gp_quicklz_decompress
- pg_catalog.gp_quicklz_destructor
- pg_catalog.gp_quicklz_validator
- pg_catalog.gp_update_ao_master_stats
- pg_catalog.gtsquery_decompress
- pg_catalog.hashbeginscan
- pg_catalog.hashbuild
- pg_catalog.hashbuildempty
- pg_catalog.hashbulkdelete
- pg_catalog.hashcostestimate
- pg_catalog.hashendscan
- pg_catalog.hashgetbitmap
- pg_catalog.hashgettuple
- pg_catalog.hashinsert
- pg_catalog.hashint2vector
- pg_catalog.hashmarkpos
- pg_catalog.hashoptions
- pg_catalog.hashrescan
- pg_catalog.hashrestrpos
- pg_catalog.hashvacuumcleanup
- pg_catalog.inet_gist_decompress
- pg_catalog.int2vectoreq
- pg_catalog.interval
- pg_catalog.interval_transform
- pg_catalog.mktinterval
- pg_catalog.numeric2point
- pg_catalog.numeric_transform
- pg_catalog.pg_current_xlog_insert_location
- pg_catalog.pg_current_xlog_location
- pg_catalog.pg_get_partition_def
- pg_catalog.pg_get_partition_rule_def
- pg_catalog.pg_get_partition_template_def
- pg_catalog.pg_is_xlog_replay_paused
- pg_catalog.pg_last_xlog_receive_location
- pg_catalog.pg_last_xlog_replay_location
- pg_catalog.pg_stat_get_backend_waiting
- pg_catalog.pg_stat_get_backend_waiting_reason
- pg_catalog.pg_switch_xlog
- pg_catalog.pg_xlogfile_name
- pg_catalog.pg_xlogfile_name_offset
- pg_catalog.pg_xlog_location_diff
- pg_catalog.pg_xlog_replay_pause
- pg_catalog.pg_xlog_replay_resume
- pg_catalog.range_gist_compress
- pg_catalog.range_gist_decompress
- pg_catalog.reltime
- pg_catalog.reltimeeq
- pg_catalog.reltimege
- pg_catalog.reltimegt
- pg_catalog.reltimein
- pg_catalog.reltimele
- pg_catalog.reltimelt
- pg_catalog.reltimene
- pg_catalog.reltimeout
- pg_catalog.reltimerecv
- pg_catalog.reltimesend
- pg_catalog.smgreq
- pg_catalog.smgrin
- pg_catalog.smgrne
- pg_catalog.smgrout
- pg_catalog.spgbeginscan
- pg_catalog.spgbuild
- pg_catalog.spgbuildempty
- pg_catalog.spgbulkdelete
- pg_catalog.spgcanreturn
- pg_catalog.spgcostestimate

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- pg_catalog.spgendscan
- pg_catalog.spggetbitmap
- pg_catalog.spggettuple
- pg_catalog.spginsert
- pg_catalog.spgmarkpos
- pg_catalog.spgoptions
- pg_catalog.spgrescan
- pg_catalog.spgrestrpos
- pg_catalog.spgvacuumcleanup
- pg_catalog.timemi
- pg_catalog.timenow
- pg_catalog.timepl
- pg_catalog.timestamp_transform
- pg_catalog.time_transform
- pg_catalog.tinterval
- pg_catalog.tintervalct
- pg_catalog.tintervalend
- pg_catalog.tintervaleq
- pg_catalog.tintervalge
- pg_catalog.tintervalgt
- pg_catalog.tintervalin
- pg_catalog.tintervalle
- pg_catalog.tintervalleneq
- pg_catalog.tintervallenge
- pg_catalog.tintervallengt
- pg_catalog.tintervallenle
- pg_catalog.tintervallenlt
- pg_catalog.tintervallenne
- pg_catalog.tintervallt
- pg_catalog.tintervalne
- pg_catalog.tintervalout
- pg_catalog.tintervalov
- pg_catalog.tintervalrecv
- pg_catalog.tintervalrel
- pg_catalog.tintervalsame
- pg_catalog.tintervalsend
- pg_catalog.tintervalstart
- pg_catalog.varbit_transform
- pg_catalog.varchar_transform

Removed Types and Composite Types

The following list includes the types and composite types removed in WarehousePG 7.

Types

- pg_catalog._reltime
- pg_catalog.reltime
- pg_catalog.smgr
- pg_catalog._tinterval
- pg_catalog.tinterval
- pg_catalog._abstime
- pg_catalog.abstim

Composite Types

- gp_toolkit.gp_size_of_partition_and_indexes_disk
- gp_toolkit.__gp_user_data_tables
- pg_catalog.pg_partition
- pg_catalog.pg_partition_columns
- pg_catalog.pg_partition_encoding
- pg_catalog.pg_partition_rule
- pg_catalog.pg_partitions
- pg_catalog.pg_partition_templates
- pg_catalog.pg_stat_partition_operations

Removed Operators

The following list includes the operators removed in WarehousePG 7.

oprname	oprcode
`pg_catalog.=`	abstimeeq
`pg_catalog.>=`	abstimege
`pg_catalog.>`	abstimegt
`pg_catalog.<=`	abstimele
`pg_catalog.<`	abstimelt
`pg_catalog.<>`	abstimene
`pg_catalog.=`	int2vectoreq
`pg_catalog.<?>`	intinterval
`pg_catalog.<#>`	mktinterval
`pg_catalog.=`	reltimeeq
`pg_catalog.>`	reltimege
`pg_catalog.>`	reltimegt
`pg_catalog.<=`	reltimele

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oprname	oprcode
pg_catalog.<	reltimelt
pg_catalog.<>	reltimene
pg_catalog.-	timemi
pg_catalog.+	timepl
pg_catalog.<<	tintervalct
pg_catalog.=	tintervaleq
pg_catalog.>=	tintervalge
pg_catalog.>	tintervalgt
pg_catalog.<=	tintervalle
pg_catalog.#=	tintervalleneq
pg_catalog.#>=	tintervallenge
pg_catalog.#>	tintervallengt
pg_catalog.#<=	tintervallenle
pg_catalog.#<	tintervallenlt
pg_catalog.#<>	tintervallenne
pg_catalog.<	tintervallt
pg_catalog.<>	tintervalne
pg_catalog.&&	tintervalov
pg_catalog.~=	tintervalsame
pg_catalog.	tintervalstart

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7.13 System Catalog Changes between WarehousePG 6 and WarehousePG 7

This topic documents changes to existing system views, system catalogs, and functions between WarehousePG 6 and WarehousePG 7.

Changes to Both System Views and System Tables

The following changes pertain to both system views and system tables:

- The `Unknown` datatype has been changed from a base type to a pseudo type.
- Sequence for `SERIAL` columns now generate positive 32-bit wide values instead of 64-bit.
- Prior to WarehousePG 7, sequence metadata was stored in separate sequence relation table; each sequence created had its own table. In WarehousePG 7, the new `pg_sequence` system table contains all sequence-related metadata.
- The `gp_toolkit` schema is now an extension.

System Table Changes

This section describes changes to existing system tables.

- The `pg_appendonly` table no longer records append-only storage options. They are now listed in `pg_class` table's `reloptions` column instead. In addition, the following columns have been removed from the `pg_appendonly` table: `blocksize`, `safefswritesize`, `compresslevel`, `checksum`, `compresstype`, `columnstore`, `blkdiridxid`, and `visimapidxid`.
- To identify the storage type of a table, search `pg_class_relam` your table. Previously, used the `relstorage` column in `pg_class`.
- In the `gp_configuration_history` table, the `desc` column has been renamed to `description`.
- A new colum, `pg_proc.prokind`, column replaces `pg_proc.proisagg` and `pg_proc.proiswindow`.
- `pg_proc.protransform` has been renamed to `pg_proc.prosupport`.
- The `pg_am` table now stores possible table access methods.
- The `relam` column of the `pg_class` table now stores per-table access method information.
- To indicate that a table is of type external, set the `relkind` column in the `pg_class` table to `f`.
- The `adsrc` column has been removed from the `pg_attdref` table.

Changed Functions

This section lists functions whose signatures have changed across their overloaded versions between WarehousePG 6 and WarehousePG 7:

- gp_toolkit.__gp_aocsseg
- gp_toolkit.__gp_aocsseg_history
- gp_toolkit.__gp_aoseg
- gp_toolkit.__gp_aoseg_history
- pg_catalog.array_agg
- pg_catalog.array_agg_finalfn
- pg_catalog.array_agg_transfn
- pg_catalog.date
- pg_catalog.date_part
- pg_catalog.gin_consistent_jsonb
- pg_catalog.gin_consistent_jsonb_path
- pg_catalog.gin_extract_jsonb
- pg_catalog.gin_extract_jsonb_path
- pg_catalog.gin_extract_jsonb_query
- pg_catalog.gin_extract_jsonb_query_path
- pg_catalog.gin_triconsistent_jsonb
- pg_catalog.gin_triconsistent_jsonb_path
- pg_catalog.gin_tsquery_triconsistent
- pg_catalog.gist_box_consistent
- pg_catalog.gist_circle_consistent
- pg_catalog.gist_point_consistent
- pg_catalog.gist_point_distance
- pg_catalog.gist_poly_consistent
- pg_catalog.gp_dist_wait_status
- pg_catalog.gp_execution_segment
- pg_catalog.gp_request_fts_probe_scan
- pg_catalog.gp_tablespace_segment_location
- pg_catalog.gtsquery_union
- pg_catalog.gtsvector_union
- pg_catalog.inet_gist_consistent
- pg_catalog.inet_gist_union
- pg_catalog.int4_pivot_accum
- pg_catalog.intinterval
- pg_catalog.isfinite
- pg_catalog.max
- pg_catalog.min
- pg_catalog.pg_create_logical_replication_slot
- pg_catalog.pg_create_physical_replication_slot
- pg_catalog.pg_cursor

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- pg_catalog.pg_event_trigger_dropped_objects
- pg_catalog.pg_get_replication_slots
- pg_catalog.pg_identify_object
- pg_catalog.pg_import_system_collations
- pg_catalog.pg_logical_slot_get_binary_changes
- pg_catalog.pg_logical_slot_get_changes
- pg_catalog.pg_logical_slot_peek_binary_changes
- pg_catalog.pg_logical_slot_peek_changes
- pg_catalog.pg_resgroup_get_status
- pg_catalog.pg_sequence_parameters
- pg_catalog.pg_show_all_settings
- pg_catalog.pg_start_backup
- pg_catalog.pg_stat_file
- pg_catalog.pg_stat_get_activity
- pg_catalog.pg_stat_get_wal_senders
- pg_catalog.pivot_sum
- pg_catalog.range_gist_consistent
- pg_catalog.range_gist_union
- pg_catalog.time
- pg_catalog.timestamp
- pg_catalog.timestamptz
- pg_catalog.to_regclass
- pg_catalog.to_regoper
- pg_catalog.to_regoperator
- pg_catalog.to_regproc
- pg_catalog.to_regprocedure
- pg_catalog.to_regtype

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7.14 Server Programmatic Interfaces

This section describes programmatic interfaces to the WarehousePG server.

- WarehousePG Partner Connector API
- Background Worker Processes

Parent topic: WarehousePG Reference Guide

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7.14.1 WarehousePG Partner Connector API

With the WarehousePG Partner Connector API (GPPC API), you can write portable WarehousePG user-defined functions (UDFs) in the C and C++ programming languages. Functions that you develop with the GPPC API require no recompilation or modification to work with older or newer WarehousePG versions.

Functions that you write to the GPPC API can be invoked using SQL in WarehousePG. The API provides a set of functions and macros that you can use to issue SQL commands through the Server Programming Interface (SPI), manipulate simple and composite data type function arguments and return values, manage memory, and handle data.

You compile the C/C++ functions that you develop with the GPPC API into a shared library. The GPPC functions are available to WarehousePG users after the shared library is installed in the WarehousePG cluster and the GPPC functions are registered as SQL UDFs.

This topic contains the following information:

- Using the GPPC API
  - Requirements
  - Header and Library Files
  - Data Types
  - Function Declaration, Arguments, and Results
  - Memory Handling
  - Working With Variable-Length Text Types
  - Error Reporting and Logging
  - SPI Functions
  - About Tuple Descriptors and Tuples
  - Set-Returning Functions
  - Table Functions
  - Limitations
  - Sample Code
- Building a GPPC Shared Library with PGXS
- Registering a GPPC Function with WarehousePG
- Packaging and Deployment Considerations
- GPPC Text Function Example
- GPPC Set-Returning Function Example

Using the GPPC API

The GPPC API shares some concepts with C language functions as defined by PostgreSQL. Refer to C-Language Functions in the PostgreSQL documentation for detailed information about developing C language functions.

The GPPC API is a wrapper that makes a C/C++ function SQL-invokable in WarehousePG. This wrapper shields GPPC functions that you write from WarehousePG library changes by normalizing table and data manipulation and SPI operations through functions and macros defined by the API.

The GPPC API includes functions and macros to:

- Operate on base and composite data types.
- Process function arguments and return values.
- Allocate and free memory.
- Log and report errors to the client.
- Issue SPI queries.
- Return a table or set of rows.
- Process tables as function input arguments.

Requirements

When you develop with the GPPC API:

- You must develop your code on a system with the same hardware and software architecture as that of your WarehousePG hosts.
- You must write the GPPC function(s) in the C or C++ programming languages.
- The function code must use the GPPC API, data types, and macros.
- The function code must *not* use the PostgreSQL C-Language Function API, header files, functions, or macros.
- The function code must *not* `#include` the `postgres.h` header file or use `PG_MODULE_MAGIC`.
- You must use only the GPPC-wrapped memory functions to allocate and free memory. See Memory Handling.
- Symbol names in your object files must not conflict with each other nor with symbols defined in the WarehousePG server. You must rename your functions or variables if you get error messages to this effect.

Header and Library Files

The GPPC header files and libraries are installed in `$GPHOME`:

- $GPHOME/include/gppc.h - the main GPPC header file
- $GPHOME/include/gppc_config.h - header file defining the GPPC version
- $GPHOME/lib/libgppc.[a, so, so.1, so.1.2] - GPPC archive and shared libraries

Data Types

The GPPC functions that you create will operate on data residing in WarehousePG. The GPPC API includes data type definitions for equivalent WarehousePG SQL data types. You must use these types in your GPPC functions.

The GPPC API defines a generic data type that you can use to represent any GPPC type. This data type is named `GppcDatum`, and is defined as follows:

```
typedef int64_t GppcDatum;
```

The following table identifies each GPPC data type and the SQL type to which it maps.

SQL Type	GPPC Type	GPPC Oid for Type
boolean	GppcBool	GppcOidBool

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SQL Type	GPPC Type	GPPC Oid for Type
char (single byte)	GppcChar	GppcOidChar
int2/smallint	GppcInt2	GppcOidInt2
int4/integer	GppcInt4	GppcOidInt4
int8/bigint	GppcInt8	GppcOidInt8
float4/real	GppcFloat4	GppcOidFloat4
float8/double	GppcFloat8	GppcOidFloat8
text	*GppcText	GppcOidText
varchar	*GppcVarChar	GppcOidVarChar
char	*GppcBpChar	GppcOidBpChar
bytea	*GppcBytea	GppcOidBytea
numeric	*GppcNumeric	GppcOidNumeric
date	GppcDate	GppcOidDate
time	GppcTime	GppcOidTime
timetz	*GppcTimeTz	GppcOidTimeTz
timestamp	GppcTimestamp	GppcOidTimestamp
timestamptz	GppcTimestampTz	GppcOidTimestampTz
anytable	GppcAnyTable	GppcOidAnyTable
oid	GppcOid	

The GPPC API treats text, numeric, and timestamp data types specially, providing functions to operate on these types.

Example GPPC base data type declarations:

```
GppcText       message;
GppcInt4       arg1;
GppcNumeric    total_sales;
```

The GPPC API defines functions to convert between the generic `GppcDatum` type and the GPPC specific types. For example, to convert from an integer to a datum:

```
GppcInt4 num = 13;
GppcDatum num_dat = GppcInt4GetDatum(num);
```

Composite Types

A composite data type represents the structure of a row or record, and is comprised of a list of field names and their data types. This structure information is typically referred to as a tuple descriptor. An instance of a composite type is typically referred to as a tuple or row. A tuple does not have a fixed layout and can contain null fields.

The GPPC API provides an interface that you can use to define the structure of, to access, and to set tuples. You will use this interface when your GPPC function takes a table as an input argument or returns table or set of record types. Using tuples in table and set returning functions is covered later in this topic.

Function Declaration, Arguments, and Results

The GPPC API relies on macros to declare functions and to simplify the passing of function arguments and results. These macros include:

Task	Macro Signature	Description
Make a function SQL-invokable	`GPPC_FUNCTION_INFO(function\_name)`	Glue to make function `function\_name` SQL-invokable.
Declare a function	`GppcDatum function\_name(GPPC_FUNCTION_ARGS)`	Declare a GPPC function named `function\_name`; every function must have this same signature.
Return the number of arguments	`GPPC_NARGS()`	Return the number of arguments passed to the function.
Fetch an argument	`GPPC_GETARG_<ARGTYPE>(arg\_num)`	Fetch the value of argument number arg_num (starts at 0), where `<ARGTYPE>` identifies the data type of the argument. For example, `GPPC_GETARG_FLOAT8(0)`.
Fetch and make a copy of a text-type argument	`GPPC_GETARG_<ARGTYPE>_COPY(arg\_num)`	Fetch and make a copy of the value of argument number arg_num (starts at 0). `<ARGTYPE>` identifies the text type (text, varchar, bpchar, bytea). For example, `GPPC_GETARG_BYTEA_COPY(1)`.
Determine if an argument is NULL	`GPPC_ARGISNULL(arg\_num)`	Return whether or not argument number `arg\_num` is NULL.
Return a result	`GPPC_RETURN_<ARGTYPE>(return\_val)`	Return the value `return\_val`, where `<ARGTYPE>` identifies the data type of the return value. For example, `GPPC_RETURN_INT4(131)`.

When you define and implement your GPPC function, you must declare it with the GPPC API using the two declarations identified above. For example, to declare a GPPC function named `add_int4s()`:

```
GPPC_FUNCTION_INFO(add_int4s);
GppcDatum add_int4s(GPPC_FUNCTION_ARGS);

GppcDatum
add_int4s(GPPC_FUNCTION_ARGS)
{
  // code here
}
```

If the `add_int4s()` function takes two input arguments of type `int4`, you use the `GPPC_GETARG_INT4(arg\_num)` macro to access the argument values. The argument index starts at 0. For example:

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```
GppcInt4  first_int = GPPC_GETARG_INT4(0);
GppcInt4  second_int = GPPC_GETARG_INT4(1);
```

If `add_int4s()` returns the sum of the two input arguments, you use the `GPPC_RETURN_INT8(return\_val)` macro to return this sum. For example:

```
GppcInt8  sum = first_int + second_int;
GPPC_RETURN_INT8(sum);
```

The complete GPPC function:

```
GPPC_FUNCTION_INFO(add_int4s);
GppcDatum add_int4s(GPPC_FUNCTION_ARGS);

GppcDatum
add_int4s(GPPC_FUNCTION_ARGS)
{
  // get input arguments
  GppcInt4    first_int = GPPC_GETARG_INT4(0);
  GppcInt4    second_int = GPPC_GETARG_INT4(1);

  // add the arguments
  GppcInt8    sum = first_int + second_int;

  // return the sum
  GPPC_RETURN_INT8(sum);
}
```

Memory Handling

The GPPC API provides functions that you use to allocate and free memory, including text memory. You must use these functions for all memory operations.

Function Name	Description
void *GppcAlloc(size_t num)	Allocate num bytes of uninitialized memory.
void *GppcAlloc0(size_t num)	Allocate num bytes of 0-initialized memory.
void *GppcRealloc(void *ptr, size_t num)	Resize pre-allocated memory.
void GppcFree(void *ptr)	Free allocated memory.

After you allocate memory, you can use system functions such as `memcpy()` to set the data.

The following example allocates an array of `GppcDatum`s and sets the array to datum versions of the function input arguments:

```
GppcDatum  *values;
int attnum = GPPC_NARGS();

// allocate memory for attnum values
values = GppcAlloc( sizeof(GppcDatum) * attnum );

// set the values
for( int i=0; i<attnum; i++ ) {
    GppcDatum d = GPPC_GETARG_DATUM(i);
    values[i] = d;
}
```

When you allocate memory for a GPPC function, you allocate it in the current context. The GPPC API includes functions to return, create, switch, and reset memory contexts.

Function Name	Description
GppcMemoryContext GppcGetCurrentMemoryContext(void)	Return the current memory context.
GppcMemoryContext GppcMemoryContextCreate(GppcMemoryContext parent)	Create a new memory context under parent.
GppcMemoryContext GppcMemoryContextSwitchTo(GppcMemoryContext context)	Switch to the memory context context.
void GppcMemoryContextReset(GppcMemoryContext context)	Reset (free) the memory in memory context context.

WarehousePG typically calls a SQL-invoked function in a per-tuple context that it creates and deletes every time the server backend processes a table row. Do not assume that memory allocated in the current memory context is available across multiple function calls.

Working With Variable-Length Text Types

The GPPC API supports the variable length text, varchar, blank padded, and byte array types. You must use the GPPC API-provided functions when you operate on these data types. Variable text manipulation functions provided in the GPPC API include those to allocate memory for, determine string length of, get string pointers for, and access these types:

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Function Name	Description
GppcText GppcAllocText(size_t len) GppcVarChar GppcAllocVarChar(size_t len) GppcBpChar GppcAllocBpChar(size_t len)	Allocate len bytes of memory for the varying length type.
GppcBytea GppcAllocBytea(size_t len)	
size_t GppcGetTextLength(GppcText s) size_t GppcGetVarCharLength(GppcVarChar s) size_t GppcGetBpCharLength(GppcBpChar s) size_t GppcGetByteaLength(GppcBytea b)	Return the number of bytes in the memory chunk.
char *GppcGetTextPointer(GppcText s) char *GppcGetVarCharPointer(GppcVarChar s) char *GppcGetBpCharPointer(GppcBpChar s) char *GppcGetByteaPointer(GppcBytea b)	Return a string pointer to the head of the memory chunk. The string is not null-terminated.
char *GppcTextGetCString(GppcText s) char *GppcVarCharGetCString(GppcVarChar s) char *GppcBpCharGetCString(GppcBpChar s)	Return a string pointer to the head of the memory chunk. The string is null-terminated.
GppcText *GppcCStringGetText(const char *s) GppcVarChar *GppcCStringGetVarChar(const char *s) GppcBpChar *GppcCStringGetBpChar(const char *s)	Build a varying-length type from a character string.

Memory returned by the `GppcGet<VLEN_ARGTYPE>Pointer()` functions may point to actual database content. Do not modify the memory content. The GPPC API provides functions to allocate memory for these types should you require it. After you allocate memory, you can use system functions such as `memcpy()` to set the data.

The following example manipulates text input arguments and allocates and sets result memory for a text string concatenation operation:

```
GppcText first_textstr = GPPC_GETARG_TEXT(0);
GppcText second_textstr = GPPC_GETARG_TEXT(1);

// determine the size of the concatenated string and allocate
// text memory of this size
size_t arg0_len = GppcGetTextLength(first_textstr);
size_t arg1_len = GppcGetTextLength(second_textstr);
GppcText retstring = GppcAllocText(arg0_len + arg1_len);

// construct the concatenated return string; copying each string
// individually
memcpy(GppcGetTextPointer(retstring), GppcGetTextPointer(first_textstr), arg0_len);
memcpy(GppcGetTextPointer(retstring) + arg0_len, GppcGetTextPointer(second_textstr), arg1_len);
```

Error Reporting and Logging

The GPPC API provides error reporting and logging functions. The API defines reporting levels equivalent to those in WarehousePG:

```
typedef enum GppcReportLevel
{
        GPPC_DEBUG1                             = 10,
        GPPC_DEBUG2                             = 11,
        GPPC_DEBUG3                             = 12,
        GPPC_DEBUG4                             = 13,
        GPPC_DEBUG                              = 14,
        GPPC_LOG                                = 15,
        GPPC_INFO                               = 17,
        GPPC_NOTICE                             = 18,
        GPPC_WARNING                        = 19,
        GPPC_ERROR                              = 20,
} GppcReportLevel;
```

(The WarehousePG `client_min_messages` server configuration parameter governs the current client logging level. The `log_min_messages` configuration parameter governs the current log-to-logfile level.)

A GPPC report includes the report level, a report message, and an optional report callback function.

Reporting and handling functions provide by the GPPC API include:

Function Name	Description
GppcReport()	Format and print/log a string of the specified report level.
GppcInstallReportCallback()	Register/install a report callback function.
GppcUninstallReportCallback()	Uninstall a report callback function.
GppcGetReportLevel()	Retrieve the level from an error report.
GppcGetReportMessage()	Retrieve the message from an error report.
GppcCheckForInterrupts()	Error out if an interrupt is pending.

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The `GppcReport()` function signature is:

```
void GppcReport(GppcReportLevel elevel, const char *fmt, ...);
```

`GppcReport()` takes a format string input argument similar to `printf()`. The following example generates an error level report message that formats a GPPC text argument:

```
GppcText  uname = GPPC_GETARG_TEXT(1);
GppcReport(GPPC_ERROR, "Unknown user name: %s", GppcTextGetCString(uname));
```

Refer to the GPPC example code for example report callback handlers.

SPI Functions

The WarehousePG Server Programming Interface (SPI) provides writers of C/C++ functions the ability to run SQL commands within a GPPC function. For additional information on SPI functions, refer toServer Programming Interface in the PostgreSQL documentation.

The GPPC API exposes a subset of PostgreSQL SPI functions. This subset enables you to issue SPI queries and retrieve SPI result values in your GPPC function. The GPPC SPI wrapper functions are:

SPI Function Name	GPPC Function Name	Description
SPI_connect()	GppcSPIConnect()	Connect to the WarehousePG server programming interface.
SPI_finish()	GppcSPIFinish()	Disconnect from the WarehousePG server programming interface.
SPI_exec()	GppcSPIExec()	Run a SQL statement, returning the number of rows.
SPI_getvalue()	GppcSPIGetValue()	Retrieve the value of a specific attribute by number from a SQL result as a character string.
GppcSPIGetDatum()	Retrieve the value of a specific attribute by number from a SQL result as a `GppcDatum`.	
GppcSPIGetValueByName()	Retrieve the value of a specific attribute by name from a SQL result as a character string.	
GppcSPIGetDatumByName()	Retrieve the value of a specific attribute by name from a SQL result as a `GppcDatum`.	

When you create a GPPC function that accesses the server programming interface, your function should comply with the following flow:

```
GppcSPIConnect();
GppcSPIExec(...)
// process the results - GppcSPIGetValue(...), GppcSPIGetDatum(...)
GppcSPIFinish()
```

You use `GppcSPIExec()` to run SQL statements in your GPPC function. When you call this function, you also identify the maximum number of rows to return. The function signature of `GppcSPIExec()` is:

```
GppcSPIResult GppcSPIExec(const char *sql_statement, long rcount);
```

`GppcSPIExec()` returns a `GppcSPIResult` structure. This structure represents SPI result data. It includes a pointer to the data, information about the number of rows processed, a counter, and a result code. The GPPC API defines this structure as follows:

```
typedef struct GppcSPIResultData
{
    struct GppcSPITupleTableData   *tuptable;
    uint32_t                       processed;
    uint32_t                       current;
    int                            rescode;
} GppcSPIResultData;
typedef GppcSPIResultData *GppcSPIResult;
```

You can set and use the `current` field in the `GppcSPIResult` structure to examine each row of the `tuptable` result data.

The following code excerpt uses the GPPC API to connect to SPI, run a simple query, loop through query results, and finish processing:

```
GppcSPIResult   result;
char            *attname = "id";
char            *query = "SELECT i, 'foo' || i AS val FROM generate_series(1, 10)i ORDER BY 1";
bool            isnull = true;

// connect to SPI
if( GppcSPIConnect() < 0 ) {
    GppcReport(GPPC_ERROR, "cannot connect to SPI");
}

// execute the query, returning all rows
result = GppcSPIExec(query, 0);

// process result
while( result->current < result->processed ) {
    // get the value of attname column as a datum, making a copy
    datum = GppcSPIGetDatumByName(result, attname, &isnull, true);

    // do something with value

    // move on to next row
    result->current++;
}

// complete processing
GppcSPIFinish();
```

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About Tuple Descriptors and Tuples

A table or a set of records contains one or more tuples (rows). The structure of each attribute of a tuple is defined by a tuple descriptor. A tuple descriptor defines the following for each attribute in the tuple:

- attribute name
- object identifier of the attribute data type
- byte length of the attribute data type
- object identifier of the attribute modifer

The GPPC API defines an abstract type, `GppcTupleDesc`, to represent a tuple/row descriptor. The API also provides functions that you can use to create, access, and set tuple descriptors:

Function Name	Description
GppcCreateTemplateTupleDesc()	Create an empty tuple descriptor with a specified number of attributes.
GppcTupleDescInitEntry()	Add an attribute to the tuple descriptor at a specified position.
GppcTupleDescNattrs()	Fetch the number of attributes in the tuple descriptor.
GppcTupleDescAttrName()	Fetch the name of the attribute in a specific position (starts at 0) in the tuple descriptor.
GppcTupleDescAttrType()	Fetch the type object identifier of the attribute in a specific position (starts at 0) in the tuple descriptor.
GppcTupleDescAttrLen()	Fetch the type length of an attribute in a specific position (starts at 0) in the tuple descriptor.
GppcTupleDescAttrTypmod()	Fetch the type modifier object identifier of an attribute in a specific position (starts at 0) in the tuple descriptor.

To construct a tuple descriptor, you first create a template, and then fill in the descriptor fields for each attribute. The signatures for these functions are:

```
GppcTupleDesc GppcCreateTemplateTupleDesc(int natts);
void GppcTupleDescInitEntry(GppcTupleDesc desc, uint16_t attno,
                            const char *attname, GppcOid typid, int32_t typmod);
```

In some cases, you may want to initialize a tuple descriptor entry from an attribute definition in an existing tuple. The following functions fetch the number of attributes in a tuple descriptor, as well as the definition of a specific attribute (by number) in the descriptor:

```
int GppcTupleDescNattrs(GppcTupleDesc tupdesc);
const char *GppcTupleDescAttrName(GppcTupleDesc tupdesc, int16_t attno);
GppcOid GppcTupleDescAttrType(GppcTupleDesc tupdesc, int16_t attno);
int16_t GppcTupleDescAttrLen(GppcTupleDesc tupdesc, int16_t attno);
int32_t GppcTupleDescAttrTypmod(GppcTupleDesc tupdesc, int16_t attno);
```

The following example initializes a two attribute tuple descriptor. The first attribute is initialized with the definition of an attribute from a different descriptor, and the second attribute is initialized to a boolean type attribute:

```
GppcTupleDesc       tdesc;
GppcTupleDesc       indesc = some_input_descriptor;

// initialize the tuple descriptor with 2 attributes
tdesc = GppcCreateTemplateTupleDesc(2);

// use third attribute from the input descriptor
GppcTupleDescInitEntry(tdesc, 1,
          GppcTupleDescAttrName(indesc, 2),
          GppcTupleDescAttrType(indesc, 2),
          GppcTupleDescAttrTypmod(indesc, 2));

// create the boolean attribute
GppcTupleDescInitEntry(tdesc, 2, "is_active", GppcOidBool, 0);
```

The GPPC API defines an abstract type, `GppcHeapTuple`, to represent a tuple/record/row. A tuple is defined by its tuple descriptor, the value for each tuple attribute, and an indicator of whether or not each value is NULL.

The GPPC API provides functions that you can use to set and access a tuple and its attributes:

Function Name	Description
GppcHeapFormTuple()	Form a tuple from an array of `GppcDatum`s.
GppcBuildHeapTupleDatum()	Form a `GppcDatum` tuple from an array of `GppcDatum`s.
GppcGetAttributeByName()	Fetch an attribute from the tuple by name.
GppcGetAttributeByNum()	Fetch an attribute from the tuple by number (starts at 1).

The signatures for the tuple-building GPPC functions are:

```
GppcHeapTuple GppcHeapFormTuple(GppcTupleDesc tupdesc, GppcDatum *values, bool *nulls);
GppcDatum    GppcBuildHeapTupleDatum(GppcTupleDesc tupdesc, GppcDatum *values, bool *nulls);
```

The following code excerpt constructs a `GppcDatum` tuple from the tuple descriptor in the above code example, and from integer and boolean input arguments to a function:

```
GppcDatum intarg = GPPC_GETARG_INT4(0);
GppcDatum boolarg = GPPC_GETARG_BOOL(1);
GppcDatum result, values[2];
bool nulls[2] = { false, false };

// construct the values array
values[0] = intarg;
values[1] = boolarg;
result = GppcBuildHeapTupleDatum( tdesc, values, nulls );
```

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Set-Returning Functions

WarehousePG UDFs whose signatures include `RETURNS SETOF RECORD` or `RETURNS TABLE( ... )` are set-returning functions.

The GPPC API provides support for returning sets (for example, multiple rows/tuples) from a GPPC function. WarehousePG calls a set-returning function (SRF) once for each row or item. The function must save enough state to remember what it was doing and to return the next row on each call. Memory that you allocate in the SRF context must survive across multiple function calls.

The GPPC API provides macros and functions to help keep track of and set this context, and to allocate SRF memory. They include:

Function/Macro Name	Description
GPPC_SRF_RESULT_DESC()	Get the output row tuple descriptor for this SRF. The result tuple descriptor is determined by an output table definition or a `DESCRIBE` function.
GPPC_SRF_IS_FIRSTCALL()	Determine if this is the first call to the SRF.
GPPC_SRF_FIRSTCALL_INIT()	Initialize the SRF context.
GPPC_SRF_PERCALL_SETUP()	Restore the context on each call to the SRF.
GPPC_SRF_RETURN_NEXT()	Return a value from the SRF and continue processing.
GPPC_SRF_RETURN_DONE()	Signal that SRF processing is complete.
GppSRFAlloc()	Allocate memory in this SRF context.
GppSRFAlloc0()	Allocate memory in this SRF context and initialize it to zero.
GppSRFSave()	Save user state in this SRF context.
GppSRFRestore()	Restore user state in this SRF context.

The `GppcFuncCallContext` structure provides the context for an SRF. You create this context on the first call to your SRF. Your set-returning GPPC function must retrieve the function context on each invocation. For example:

```
// set function context
GppcFuncCallContext fctx;
if (GPPC_SRF_IS_FIRSTCALL()) {
    fctx = GPPC_SRF_FIRSTCALL_INIT();
}
fctx = GPPC_SRF_PERCALL_SETUP();
// process the tuple
```

The GPPC function must provide the context when it returns a tuple result or to indicate that processing is complete. For example:

```
GPPC_SRF_RETURN_NEXT(fctx, result_tuple);
// or
GPPC_SRF_RETURN_DONE(fctx);
```

Use a `DESCRIBE` function to define the output tuple descriptor of a function that uses the `RETURNS SETOF RECORD` clause. Use the `GPPC_SRF_RESULT_DESC()` macro to get the output tuple descriptor of a function that uses the `RETURNS TABLE( ... )` clause.

Refer to the GPPC Set-Returning Function Example for a set-returning function code and deployment example.

Table Functions

The GPPC API provides the `GppcAnyTable` type to pass a table to a function as an input argument, or to return a table as a function result.

Table-related functions and macros provided in the GPPC API include:

Function/Macro Name	Description
GPPC_GETARG_ANYTABLE()	Fetch an anytable function argument.
GPPC_RETURN_ANYTABLE()	Return the table.
GppcAnyTableGetTupleDesc()	Fetch the tuple descriptor for the table.
GppcAnyTableGetNextTuple()	Fetch the next row in the table.

You can use the `GPPC_GETARG_ANYTABLE()` macro to retrieve a table input argument. When you have access to the table, you can examine the tuple descriptor for the table using the `GppcAnyTableGetTupleDesc()` function. The signature of this function is:

```
GppcTupleDesc GppcAnyTableGetTupleDesc(GppcAnyTable t);
```

For example, to retrieve the tuple descriptor of a table that is the first input argument to a function:

```
GppcAnyTable     intbl;
GppcTupleDesc    in_desc;

intbl = GPPC_GETARG_ANYTABLE(0);
in_desc = GppcAnyTableGetTupleDesc(intbl);
```

The `GppcAnyTableGetNextTuple()` function fetches the next row from the table. Similarly, to retrieve the next tuple from the table above:

```
GppcHeapTuple    ntuple;

ntuple = GppcAnyTableGetNextTuple(intbl);
```

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Limitations

The GPPC API does not support the following operators with WarehousePG version 5.0.x:

- integer || integer
- integer = text
- text < integer

Sample Code

The gppc test directory in the WarehousePG github repository includes sample GPPC code:

- `gppc_demo/` - sample code exercising GPPC SPI functions, error reporting, data type argument and return macros, set-returning functions, and encoding functions
- `tabfunc_gppc_demo/` - sample code exercising GPPC table and set-returning functions

Building a GPPC Shared Library with PGXS

You compile functions that you write with the GPPC API into one or more shared libraries that the WarehousePG server loads on demand.

You can use the PostgreSQL build extension infrastructure (PGXS) to build the source code for your GPPC functions against a WarehousePG installation. This framework automates common build rules for simple modules. If you have a more complicated use case, you will need to write your own build system.

To use the PGXS infrastructure to generate a shared library for functions that you create with the GPPC API, create a simple `Makefile` that sets PGXS-specific variables.

> **Note** Refer to Extension Building Infrastructure in the PostgreSQL documentation for information about the `Makefile` variables supported by PGXS.

For example, the following `Makefile` generates a shared library named `sharedlib_name.so` from two C source files named `src1.c` and `src2.c`:

```
MODULE_big = sharedlib_name
OBJS = src1.o src2.o
PG_CPPFLAGS = -I$(shell $(PG_CONFIG) --includedir)
SHLIB_LINK = -L$(shell $(PG_CONFIG) --libdir) -lgppc

PG_CONFIG = pg_config
PGXS := $(shell $(PG_CONFIG) --pgxs)
include $(PGXS)
```

`MODULE_big` identifes the base name of the shared library generated by the `Makefile`.

`PG_CPPFLAGS` adds the WarehousePG installation include directory to the compiler header file search path.

`SHLIB_LINK` adds the WarehousePG installation library directory to the linker search path. This variable also adds the GPPC library (`-lgppc`) to the link command.

The `PG_CONFIG` and `PGXS` variable settings and the `include` statement are required and typically reside in the last three lines of the `Makefile`.

Registering a GPPC Function with WarehousePG

Before users can invoke a GPPC function from SQL, you must register the function with WarehousePG.

Registering a GPPC function involves mapping the GPPC function signature to a SQL user-defined function. You define this mapping with the `CREATE FUNCTION .. AS` command specifying the GPPC shared library name. You may choose to use the same name or differing names for the GPPC and SQL functions.

Sample `CREATE FUNCTION ... AS` syntax follows:

```
CREATE FUNCTION <sql_function_name>(<arg>[, ...]) RETURNS <return_type>
  AS '<shared_library_path>'[, '<gppc_function_name>']
LANGUAGE C STRICT [WITH (DESCRIBE=<describe_function>)];
```

You may omit the shared library `.so` extension when you specify `shared\_library\_path`.

The following command registers the example `add_int4s()` function referenced earlier in this topic to a SQL UDF named `add_two_int4s_gppc()` if the GPPC function was compiled and linked in a shared library named `gppc_try.so`:

```
CREATE FUNCTION add_two_int4s_gppc(int4, int4) RETURNS int8
  AS 'gppc_try.so', 'add_int4s'
LANGUAGE C STRICT;
```

About Dynamic Loading

You specify the name of the GPPC shared library in the SQL `CREATE FUNCTION ... AS` command to register a GPPC function in the shared library with WarehousePG. The WarehousePG dynamic loader loads a GPPC shared library file into memory the first time that a user invokes a user-defined function linked in that shared library. If you do not provide an absolute path to the shared library in the `CREATE FUNCTION ... AS` command, WarehousePG attempts to locate the library using these ordered steps:

1. If the shared library file path begins with the string `$libdir`, WarehousePG looks for the file in the PostgreSQL package library directory. Run the `pg_config --pkglibdir` command to determine the location of this directory.
2. If the shared library file name is specified without a directory prefix, WarehousePG searches for the file in the directory identified by the `dynamic_library_path` server configuration parameter value.
3. The current working directory.

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Packaging and Deployment Considerations

You must package the GPPC shared library and SQL function registration script in a form suitable for deployment by the WarehousePG administrator in the WarehousePG cluster. Provide specific deployment instructions for your GPPC package.

When you construct the package and deployment instructions, take into account the following:

- Consider providing a shell script or program that the WarehousePG administrator runs to both install the shared library to the desired file system location and register the GPPC functions.
- The GPPC shared library must be installed to the same file system location on the coordinator host and on every segment host in the WarehousePG cluster.
- The `gpadmin` user must have permission to traverse the complete file system path to the GPPC shared library file.
- The file system location of your GPPC shared library after it is installed in the WarehousePG deployment determines how you reference the shared library when you register a function in the library with the `CREATE FUNCTION ... AS` command.
- Create a `.sql` script file that registers a SQL UDF for each GPPC function in your GPPC shared library. The functions that you create in the `.sql` registration script must reference the deployment location of the GPPC shared library. Include this script in your GPPC deployment package.
- Document the instructions for running your GPPC package deployment script, if you provide one.
- Document the instructions for installing the GPPC shared library if you do not include this task in a package deployment script.
- Document the instructions for installing and running the function registration script if you do not include this task in a package deployment script.

GPPC Text Function Example

In this example, you develop, build, and deploy a GPPC shared library and register and run a GPPC function named `concat_two_strings`. This function uses the GPPC API to concatenate two string arguments and return the result.

You will develop the GPPC function on your WarehousePG coordinator host. Deploying the GPPC shared library that you create in this example requires administrative access to your WarehousePG cluster.

Perform the following procedure to run the example:

1. Log in to the WarehousePG coordinator host and set up your environment. For example:

   ```
   $ ssh gpadmin@<gpcoordinator>
   gpadmin@gpcoordinator$ . /usr/edb/whpg7/greenplum_path.sh
   ```

2. Create a work directory and navigate to the new directory. For example:

   ```
   gpadmin@gpcoordinator$ mkdir gppc_work
   gpadmin@gpcoordinator$ cd gppc_work
   ```

3. Prepare a file for GPPC source code by opening the file in the editor of your choice. For example, to open a file named `gppc_concat.c` using `vi`:

   ```
   gpadmin@gpcoordinator$ vi gppc_concat.c
   ```

4. Copy/paste the following code into the file:

   ```
   #include <stdio.h>
   #include <string.h>
   #include "gppc.h"

   // make the function SQL-invokable
   GPPC_FUNCTION_INFO(concat_two_strings);

   // declare the function
   GppcDatum concat_two_strings(GPPC_FUNCTION_ARGS);

   GppcDatum
   concat_two_strings(GPPC_FUNCTION_ARGS)
   {
       // retrieve the text input arguments
       GppcText arg0 = GPPC_GETARG_TEXT(0);
       GppcText arg1 = GPPC_GETARG_TEXT(1);

       // determine the size of the concatenated string and allocate
       // text memory of this size
       size_t arg0_len = GppcGetTextLength(arg0);
       size_t arg1_len = GppcGetTextLength(arg1);
       GppcText retstring = GppcAllocText(arg0_len + arg1_len);

       // construct the concatenated return string
       memcpy(GppcGetTextPointer(retstring), GppcGetTextPointer(arg0), arg0_len);
       memcpy(GppcGetTextPointer(retstring) + arg0_len, GppcGetTextPointer(arg1), arg1_len);

       GPPC_RETURN_TEXT( retstring );
   }
   ```

   The code declares and implements the `concat_two_strings()` function. It uses GPPC data types, macros, and functions to get the function arguments, allocate memory for the concatenated string, copy the arguments into the new string, and return the result.

5. Save the file and exit the editor.

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6. Open a file named `Makefile` in the editor of your choice. Copy/paste the following text into the file:

```
MODULE_big = gppc_concat
OBJS = gppc_concat.o

PG_CONFIG = pg_config
PGXS := $(shell $(PG_CONFIG) --pgxs)

PG_CPPFLAGS = -I$(shell $(PG_CONFIG) --includedir)
SHLIB_LINK = -L$(shell $(PG_CONFIG) --libdir) -lgppc
include $(PGXS)
```

7. Save the file and exit the editor.

8. Build a GPPC shared library for the `concat_two_strings()` function. For example:

```
gpadmin@gpcoordinator$ make all
```

   The `make` command generates a shared library file named `gppc_concat.so` in the current working directory.

9. Copy the shared library to your WarehousePG installation. You must have WarehousePG administrative privileges to copy the file. For example:

```
gpadmin@gpcoordinator$ cp gppc_concat.so /usr/edb/whpg7/lib/postgresql/
```

10. Copy the shared library to every host in your WarehousePG installation. For example, if `seghostfile` contains a list, one-host-per-line, of the segment hosts in your WarehousePG cluster:

```
gpadmin@gpcoordinator$ gpsync -v -f seghostfile /usr/edb/whpg7/lib/postgresql/gppc_concat.so =:/usr/edb/whpg7/lib/postgresql/gppc_concat.so
```

11. Open a `psql` session. For example:

```
gpadmin@gpcoordinator$ psql -d testdb
```

12. Register the GPPC function named `concat_two_strings()` with WarehousePG, For example, to map the WarehousePG function `concat_with_gppc()` to the GPPC `concat_two_strings()` function:

```
testdb=# CREATE FUNCTION concat_with_gppc(text, text) RETURNS text
  AS 'gppc_concat', 'concat_two_strings'
LANGUAGE C STRICT;
```

13. Run the `concat_with_gppc()` function. For example:

```
testdb=# SELECT concat_with_gppc( 'happy', 'monday' );
 concat_with_gppc
------------------
 happymonday
(1 row)
```

GPPC Set-Returning Function Example

In this example, you develop, build, and deploy a GPPC shared library. You also create and run a `.sql` registration script for a GPPC function named `return_tbl()`. This function uses the GPPC API to take an input table with an integer and a text column, determine if the integer column is greater than 13, and returns a result table with the input integer column and a boolean column identifying whether or not the integer is greater than 13. `return_tbl()` utilizes GPPC API reporting and SRF functions and macros.

You will develop the GPPC function on your WarehousePG coordinator host. Deploying the GPPC shared library that you create in this example requires administrative access to your WarehousePG cluster.

Perform the following procedure to run the example:

1. Log in to the WarehousePG coordinator host and set up your environment. For example:

```
$ ssh gpadmin@<gpcoordinator>
gpadmin@gpcoordinator$ . /usr/edb/whpg7/greenplum_path.sh
```

2. Create a work directory and navigate to the new directory. For example:

```
gpadmin@gpcoordinator$ mkdir gppc_work
gpadmin@gpcoordinator$ cd gppc_work
```

3. Prepare a source file for GPPC code by opening the file in the editor of your choice. For example, to open a file named `gppc_concat.c` using `vi`:

```
gpadmin@gpcoordinator$ vi gppc_rettbl.c
```

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4. Copy/paste the following code into the file:

```
#include <stdio.h>
#include <string.h>
#include "gppc.h"

// initialize the logging level
GppcReportLevel level = GPPC_INFO;

// make the function SQL-invokable and declare the function
GPPC_FUNCTION_INFO(return_tbl);
GppcDatum return_tbl(GPPC_FUNCTION_ARGS);

GppcDatum
return_tbl(GPPC_FUNCTION_ARGS)
{
    GppcFuncCallContext fctx;
    GppcAnyTable    intbl;
    GppcHeapTuple   intuple;
    GppcTupleDesc   in_tupdesc, out_tupdesc;
    GppcBool        resbool = false;
    GppcDatum       result, boolres, values[2];
    bool        nulls[2] = {false, false};

    // single input argument - the table
    intbl = GPPC_GETARG_ANYTABLE(0);

    // set the function context
    if (GPPC_SRF_IS_FIRSTCALL()) {
        fctx = GPPC_SRF_FIRSTCALL_INIT();
    }
    fctx = GPPC_SRF_PERCALL_SETUP();

    // get the tuple descriptor for the input table
    in_tupdesc  = GppcAnyTableGetTupleDesc(intbl);

    // retrieve the next tuple
    intuple = GppcAnyTableGetNextTuple(intbl);
    if( intuple == NULL ) {
      // no more tuples, conclude
      GPPC_SRF_RETURN_DONE(fctx);
    }

    // get the output tuple descriptor and verify that it is
    // defined as we expect
    out_tupdesc = GPPC_SRF_RESULT_DESC();
    if (GppcTupleDescNattrs(out_tupdesc) != 2                ||
        GppcTupleDescAttrType(out_tupdesc, 0) != GppcOidInt4 ||
        GppcTupleDescAttrType(out_tupdesc, 1) != GppcOidBool) {
        GppcReport(GPPC_ERROR, "INVALID out_tupdesc tuple");
    }

    // log the attribute names of the output tuple descriptor
    GppcReport(level, "output tuple descriptor attr0 name: %s", GppcTupleDescAttrName(out_tupdesc, 0));
    GppcReport(level, "output tuple descriptor attr1 name: %s", GppcTupleDescAttrName(out_tupdesc, 1));

    // retrieve the attribute values by name from the tuple
    bool text_isnull, int_isnull;
    GppcDatum intdat = GppcGetAttributeByName(intuple, "id", &int_isnull);
    GppcDatum textdat = GppcGetAttributeByName(intuple, "msg", &text_isnull);

    // convert datum to specific type
    GppcInt4 intarg = GppcDatumGetInt4(intdat);
    GppcReport(level, "id: %d", intarg);
    GppcReport(level, "msg: %s", GppcTextGetCString(GppcDatumGetText(textdat)));

    // perform the >13 check on the integer
    if( !int_isnull && (intarg > 13) ) {
        // greater than 13?
        resbool = true;
        GppcReport(level, "id is greater than 13!");
    }

    // values are datums; use integer from the tuple and
    // construct the datum for the boolean return
    values[0] = intdat;
    boolres = GppcBoolGetDatum(resbool);
    values[1] = boolres;

    // build a datum tuple and return
    result = GppcBuildHeapTupleDatum(out_tupdesc, values, nulls);
    GPPC_SRF_RETURN_NEXT(fctx, result);

}
```

The code declares and implements the `return_tbl()` function. It uses GPPC data types, macros, and functions to fetch the function arguments, examine tuple descriptors, build the return tuple, and return the result. The function also uses the SRF macros to keep track of the tuple context across function calls.

5. Save the file and exit the editor.

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6. Open a file named `Makefile` in the editor of your choice. Copy/paste the following text into the file:

```
MODULE_big = gppc_rettbl
OBJS = gppc_rettbl.o

PG_CONFIG = pg_config
PGXS := $(shell $(PG_CONFIG) --pgxs)

PG_CPPFLAGS = -I$(shell $(PG_CONFIG) --includedir)
SHLIB_LINK = -L$(shell $(PG_CONFIG) --libdir) -lgppc
include $(PGXS)
```

7. Save the file and exit the editor.

8. Build a GPPC shared library for the `return_tbl()` function. For example:

```
gpadmin@gpcoordinator$ make all
```

   The `make` command generates a shared library file named `gppc_rettbl.so` in the current working directory.

9. Copy the shared library to your WarehousePG installation. You must have WarehousePG administrative privileges to copy the file. For example:

```
gpadmin@gpcoordinator$ cp gppc_rettbl.so /usr/edb/whpg7/lib/postgresql/
```

   This command copies the shared library to `$libdir`

10. Copy the shared library to every host in your WarehousePG installation. For example, if `seghostfile` contains a list, one-host-per-line, of the segment hosts in your WarehousePG cluster:

```
gpadmin@gpcoordinator$ gpsync -v -f seghostfile /usr/edb/whpg7/lib/postgresql/gppc_rettbl.so =:/usr/edb/whpg7/lib/postgresql/gppc_rettbl.so
```

11. Create a `.sql` file to register the GPPC `return_tbl()` function. Open a file named `gppc_rettbl_reg.sql` in the editor of your choice.

12. Copy/paste the following text into the file:

```
CREATE FUNCTION rettbl_gppc(anytable) RETURNS TABLE(id int4, thirteen bool)
  AS 'gppc_rettbl', 'return_tbl'
LANGUAGE C STRICT;
```

13. Register the GPPC function by running the script you just created. For example, to register the function in a database named `testdb`:

```
gpadmin@gpcoordinator$ psql -d testdb -f gppc_rettbl_reg.sql
```

14. Open a `psql` session. For example:

```
gpadmin@gpcoordinator$ psql -d testdb
```

15. Create a table with some test data. For example:

```
CREATE TABLE gppc_testtbl( id int, msg text );
INSERT INTO gppc_testtbl VALUES (1, 'f1');
INSERT INTO gppc_testtbl VALUES (7, 'f7');
INSERT INTO gppc_testtbl VALUES (10, 'f10');
INSERT INTO gppc_testtbl VALUES (13, 'f13');
INSERT INTO gppc_testtbl VALUES (15, 'f15');
INSERT INTO gppc_testtbl VALUES (17, 'f17');
```

16. Run the `rettbl_gppc()` function. For example:

```
testdb=# SELECT * FROM rettbl_gppc(TABLE(SELECT * FROM gppc_testtbl));
 id | thirteen
----+----------
  1 | f
  7 | f
 13 | f
 15 | t
 17 | t
 10 | f
(6 rows)
```

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7.14.2 Developing a Background Worker Process

WarehousePG can be extended to run user-supplied code in separate processes. Such processes are started, stopped, and monitored by `postgres`, which permits them to have a lifetime closely linked to the server's status. These processes have the option to attach to WarehousePG's shared memory area and to connect to databases internally; they can also run multiple transactions serially, just like a regular client-connected server process. Also, by linking to `libpq` they can connect to the server and behave like a regular client application.

> **Caution** There are considerable robustness and security risks in using background worker processes because, being written in the `C` language, they have unrestricted access to data. Administrators wishing to enable modules that include background worker processes should exercise extreme caution. Only carefully audited modules should be permitted to run background worker processes.

Background workers can be initialized at the time that WarehousePG is started by including the module name in the shared_preload_libraries server configuration parameter. A module wishing to run a background worker can register it by calling `RegisterBackgroundWorker(BackgroundWorker *worker)` from its `_PG_init()`. Background workers can also be started after the system is up and running by calling the function `RegisterDynamicBackgroundWorker(BackgroundWorker *worker, BackgroundWorkerHandle **handle)`. Unlike `RegisterBackgroundWorker`, which can only be called from within the `postmaster`, `RegisterDynamicBackgroundWorker` must be called from a regular backend.

The structure `BackgroundWorker` is defined thus:

```
typedef void (*bgworker_main_type)(Datum main_arg);
typedef struct BackgroundWorker
{
    char        bgw_name[BGW_MAXLEN];
    int         bgw_flags;
    BgWorkerStartTime bgw_start_time;
    int         bgw_restart_time;       /* in seconds, or BGW_NEVER_RESTART */
    bgworker_main_type bgw_main;
    char        bgw_library_name[BGW_MAXLEN];   /* only if bgw_main is NULL */
    char        bgw_function_name[BGW_MAXLEN];  /* only if bgw_main is NULL */
    Datum       bgw_main_arg;
    int         bgw_notify_pid;
} BackgroundWorker;
```

`bgw_name` is a string to be used in log messages, process listings and similar contexts.

`bgw_flags` is a bitwise-or'd bit mask indicating the capabilities that the module wants. Possible values are `BGWORKER_SHMEM_ACCESS` (requesting shared memory access) and `BGWORKER_BACKEND_DATABASE_CONNECTION` (requesting the ability to establish a database connection, through which it can later run transactions and queries). A background worker using `BGWORKER_BACKEND_DATABASE_CONNECTION` to connect to a database must also attach shared memory using `BGWORKER_SHMEM_ACCESS`, or worker start-up will fail.

`bgw_start_time` is the server state during which `postgres` should start the process; it can be one of `BgWorkerStart_PostmasterStart` (start as soon as `postgres` itself has finished its own initialization; processes requesting this are not eligible for database connections), `BgWorkerStart_ConsistentState` (start as soon as a consistent state has been reached in a hot standby, allowing processes to connect to databases and run read-only queries), and `BgWorkerStart_RecoveryFinished` (start as soon as the system has entered normal read-write state). Note the last two values are equivalent in a server that's not a hot standby. Note that this setting only indicates when the processes are to be started; they do not stop when a different state is reached.

`bgw_restart_time` is the interval, in seconds, that `postgres` should wait before restarting the process, in case it crashes. It can be any positive value, or `BGW_NEVER_RESTART`, indicating not to restart the process in case of a crash.

`bgw_main` is a pointer to the function to run when the process is started. This function must take a single argument of type `Datum` and return `void`. `bgw_main_arg` will be passed to it as its only argument. Note that the global variable `MyBgworkerEntry` points to a copy of the `BackgroundWorker` structure passed at registration time. `bgw_main` may be NULL; in that case, `bgw_library_name` and `bgw_function_name` will be used to determine the entry point. This is useful for background workers launched after postmaster startup, where the postmaster does not have the requisite library loaded.

`bgw_library_name` is the name of a library in which the initial entry point for the background worker should be sought. It is ignored unless `bgw_main` is NULL. But if `bgw_main` is NULL, then the named library will be dynamically loaded by the worker process and `bgw_function_name` will be used to identify the function to be called.

`bgw_function_name` is the name of a function in a dynamically loaded library which should be used as the initial entry point for a new background worker. It is ignored unless `bgw_main` is NULL.

`bgw_notify_pid` is the PID of a WarehousePG backend process to which the postmaster should send `SIGUSR1` when the process is started or exits. It should be 0 for workers registered at postmaster startup time, or when the backend registering the worker does not wish to wait for the worker to start up. Otherwise, it should be initialized to `MyProcPid`.

Once running, the process can connect to a database by calling `BackgroundWorkerInitializeConnection(` char *dbname `,` char *username `)`. This allows the process to run transactions and queries using the `SPI` interface. If dbname is NULL, the session is not connected to any particular database, but shared catalogs can be accessed. If username is NULL, the process will run as the superuser created during `initdb`. BackgroundWorkerInitializeConnection can only be called once per background process, it is not possible to switch databases.

Signals are initially blocked when control reaches the `bgw_main` function, and must be unblocked by it; this is to allow the process to customize its signal handlers, if necessary. Signals can be unblocked in the new process by calling `BackgroundWorkerUnblockSignals` and blocked by calling `BackgroundWorkerBlockSignals`.

If `bgw_restart_time` for a background worker is configured as `BGW_NEVER_RESTART`, or if it exits with an exit code of 0 or is terminated by `TerminateBackgroundWorker`, it will be automatically unregistered by the postmaster on exit. Otherwise, it will be restarted after the time period configured via `bgw_restart_time`, or immediately if the postmaster reinitializes the cluster due to a backend failure. Backends which need to suspend execution only temporarily should use an interruptible sleep rather than exiting; this can be achieved by calling `WaitLatch()`. Make sure the `WL_POSTMASTER_DEATH` flag is set when calling that function, and verify the return code for a prompt exit in the emergency case that `postgres` itself has terminated.

When a background worker is registered using the `RegisterDynamicBackgroundWorker` function, it is possible for the backend performing the registration to obtain information regarding the status of the worker. Backends wishing to do this should pass the address of a `BackgroundWorkerHandle *` as the second argument to `RegisterDynamicBackgroundWorker`. If the worker is successfully registered, this pointer will be initialized with an opaque handle that can subsequently be passed to `GetBackgroundWorkerPid(` BackgroundWorkerHandle * `,` pid_t * `)` or `TerminateBackgroundWorker(` BackgroundWorkerHandle * `)`. `GetBackgroundWorkerPid` can be used to poll the status of the worker: a return value of `BGWH_NOT_YET_STARTED` indicates that the worker has not yet been started by the postmaster; `BGWH_STOPPED` indicates that it has been started but is no longer running; and `BGWH_STARTED` indicates that it is currently running. In this last case, the PID will also be returned via the second argument. `TerminateBackgroundWorker` causes the postmaster to send `SIGTERM` to the worker if it is running, and to unregister it as soon as it is not.

In some cases, a process which registers a background worker may wish to wait for the worker to start up. This can be accomplished by initializing `bgw_notify_pid` to `MyProcPid` and then passing the `BackgroundWorkerHandle *` obtained at registration time to `WaitForBackgroundWorkerStartup(` BackgroundWorkerHandle *handle `,` pid_t * `)` function. This function will block until the postmaster has attempted to start the background worker, or until the postmaster dies. If the background runner is running, the return value will `BGWH_STARTED`, and the PID will be written to the provided address. Otherwise, the return value will be `BGWH_STOPPED` or `BGWH_POSTMASTER_DIED`.

The `worker_spi` contrib module contains a working example, which demonstrates some useful techniques.

The maximum number of registered background workers is limited by the `max_worker_processes` server configuration parameter.

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8 About this Documentation

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9 Migrating gphdfs External Tables to PXF

You may be using the `gphdfs` external table protocol in a WarehousePG version 4 or 5 cluster to access data stored in Hadoop. WarehousePG version 6 removes support for the `gphdfs` protocol. To maintain access to Hadoop data in WarehousePG 6, you must migrate your `gphdfs` external tables to use the WarehousePG Platform Extension Framework (PXF). This involves setting up PXF and creating new external tables that use the `pxf` external table protocol.

To migrate your `gphdfs` external tables to use the `pxf` external table protocol, you:

1. Prepare for the migration.
2. Map configuration properties, and then [set up PXF] (#id_cfg_prop).
3. Create a new `pxf` external table to replace each `gphdfs` external table.
4. Verify access to Hadoop files with the `pxf` external tables.
5. Remove the `gphdfs` external tables.
6. Revoke privileges to the `gphdfs` protocol.
7. Migrate data to WarehousePG 6.

> **Note: Note:** If you are migrating `gphdfs` from a WarehousePG 5 installation, you perform the migration in the order above in your WarehousePG 5 cluster before you migrate data to WarehousePG 6.

> **Note: Note:** If you are migrating `gphdfs` from a WarehousePG 4 installation, you perform the migration in a similar order. However, since PXF is not available in WarehousePG 4, you must perform certain actions in the WarehousePG 6 installation before you migrate the data:
>
> 1. WarehousePG 4: Prepare for the migration.
> 2. WarehousePG 6:
>   1. Install and configure the WarehousePG 6 software.
>   2. Map configuration properties, and then install and set up PXF.
>   3. Create a new `pxf` external table to replace each `gphdfs` external table.
>   4. Verify access to Hadoop files with the `pxf` external tables.
> 3. WarehousePG 4:
>   1. Remove the `gphdfs` external tables.
>   2. Revoke privileges to the `gphdfs` protocol.
> 4. Migrate WarehousePG 4 data to WarehousePG 6.

Preparing for the Migration

As you prepare for migrating from `gphdfs` to PXF:

1. Determine which `gphdfs` tables you want to migrate.

   You can run the following query to list the `gphdfs` external tables in a database:

   ```
   SELECT n.nspname, d.objid::regclass as
   tablename
     FROM pg_depend d
     JOIN pg_exttable x ON ( d.objid = x.reloid )
     JOIN pg_extprotocol p ON ( p.oid = d.refobjid )
     JOIN pg_class c ON ( c.oid = d.objid )
     JOIN pg_namespace n ON ( c.relnamespace = n.oid )
   WHERE d.refclassid = 'pg_extprotocol'::regclass AND p.ptcname = 'gphdfs';
   ```

2. For each table that you choose to migrate, identify the format of the external data and the column definitions. Also identify the options with which the `gphdfs` table was created. You can use the `\dt+` SQL meta-command to obtain this information. For example:

   ```
   \d+ public.gphdfs_writable_parquet
        External table
   "public.gphdfs_writable_parquet"
    Column |  Type   | Modifiers | Storage  | Description
   --------+---------+-----------+----------+-------------
    id     | integer |           | plain    |
    msg    | text    |           | extended |
   Type:
   writable
   Encoding: UTF8
   Format type: parquet
   Format options: formatter 'gphdfs_export'
   External options:
   {}
   External location: gphdfs://hdfshost:8020/data/dir1/gphdfs_writepq?codec=GZIP
   Execute on: all
   segments
   ```

3. Save the information that you gathered above.

Setting Up PXF

PXF does not use the following `gphdfs` configuration options:

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gphdfs Configuration Option	Description	pxf Consideration
HADOOP_HOME	Environment variable that identifies the Hadoop installation directory	Not applicable; PXF is bundled with the required dependent Hadoop libraries and JARs
CLASSPATH	Environment variable that identifies the locations of Hadoop JAR and configuration files	Not applicable, PXF automatically includes the Hadoop libraries, JARs, and configuration files that it bundles in the `CLASSPATH`. PXF also automatically includes in the `CLASSPATH` user-registered dependencies found in the `$PXF_CONF/lib` (PXF 5.x) or `$PXF_BASE/lib` (PXF 6.x) directory.
gp_hadoop_target_version	Server configuration parameter that identifies the Hadoop distribution	Not applicable, PXF works out-of-the-box with the different Hadoop distributions
gp_hadoop_home	Server configuration parameter that identifies the Hadoop installation directory	Not applicable, PXF works out-of-the-box with the different Hadoop distributions

Configuration properties required by PXF, and the `gphdfs` equivalent, if applicable, include:

Configuration Item	Description	gphdfs Config	pxf Config
JAVA_HOME	Environment variable that identifies the Java installation directory	Set `JAVA_HOME` on each segment host	Set `JAVA_HOME` in the `$PXF_CONF/conf/pxf-env.sh` (PXF 5.x) or `$PXF_BASE/conf/pxf-env.sh` (PXF 6.x) configuration file.
JVM option settings	Options with which to start the JVM	Set options in the `GP_JAVA_OPT` environment variable in `hadoop_env.sh`	Set options in the `PXF_JVM_OPTS` environment variable in `$PXF_CONF/conf/pxf-env.sh` (PXF 5.x) or `$PXF_BASE/conf/pxf-env.sh` (PXF 6.x).
PXF Server	PXF server configuration for Hadoop	Not applicable	Configure a PXF server for Hadoop
Privileges	The WarehousePG privileges required to create external tables in the given protocol	Grant `SELECT` and `INSERT` privileges on the `gphdfs` protocol to appropriate users	Grant `SELECT` and `INSERT` privileges on the `pxf` protocol to appropriate users

After you determine the equivalent PXF configuration properties, you will:

1. Update the Java version installed on each WarehousePG host, if necessary. PXF supports Java version 8 and 11. If your WarehousePG cluster hosts are running Java 7, upgrade to Java version 8 or 11 as described in Installing Java for PXF. Note the `$JAVA_HOME` setting.
2. If you are migrating from WarehousePG 4, *or* you have not previously used PXF in your WarehousePG 5 installation:
    1. Install the newest version of the independent PXF distribution on your WarehousePG hosts.
    2. Inform PXF of the $JAVA_HOME setting by specifying its value in the `pxf-env.sh` configuration file.
        - Edit the `pxf-env.sh` file on the WarehousePG coordinator node.

          ```
          gpadmin@gpcoordinator$ vi /usr/local/pxf-gp7/conf/pxf-env.sh
          ```

        - Locate the `JAVA_HOME` setting in the `pxf-env.sh` file, uncomment if necessary, and set it to your `$JAVA_HOME` value. For example:

          ```
          export JAVA_HOME=/usr/lib/jvm/java-1.8.0-openjdk/jre/
          ```

    3. Register the PXF extension with WarehousePG:

       ```
       gpadmin@gpcoordinator$ pxf cluster register
       ```

    4. Enable the PXF extension and grant users access to PXF.
3. Configure the PXF Hadoop Connectors. This procedure creates a PXF server configuration that provides PXF the information that it requires to access Hadoop. This procedure also synchronizes the configuration changes to all hosts in your WarehousePG cluster.
4. Start or restart PXF in your WarehousePG cluster:

   ```
   gpadmin@gpcoordinator$ pxf cluster start
   ```

Creating a PXF External Table

`gphdfs` and `pxf` are both external table protocols. Creating an external table using these protocols is similar. You specify the external table name and its column definitions. You also specify `LOCATION` and `FORMAT` clauses. `gphdfs` and `pxf` use information in these clauses to determine the location and type of the external data.

Mapping the LOCATION Clause

The `LOCATION` clause of an external table identifies the external table protocol, location of the external data, and protocol- and operation-specific custom options.

The format of `gphdfs`'s `LOCATION` clause is as follows:

```
LOCATION('gphdfs://<hdfs_host>:<hdfs_port>/<path-to-data>?[&<custom-option>=<value>[...]]')
```

PXF's `LOCATION` clause takes the following format when you access data stored on Hadoop:

```
LOCATION('pxf://<path-to-data>?PROFILE=<profile_name>[&SERVER=<server_name>][&<custom-option>=<value>[...]]')
```

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You are not required to specify the HDFS host and port number when you create a PXF external table. PXF obtains this information from the `default` server configuration, or from the server configuration name that you specify in `<server_name>`.

Refer to Creating an External Table in the PXF documentation for more information about the PXF `CREATE EXTERNAL TABLE` syntax and keywords.

When you create an external table specifying the `gphdfs` protocol, you identify the format of the external data in the `FORMAT` clause (discussed in the next section). PXF uses a `PROFILE` option in the `LOCATION` clause to identify the source and type of the external data.

Data Format	pxf PROFILE
Avro	hdfs:avro
Parquet	hdfs:parquet
Text	hdfs:text

Refer to Connectors, Data Formats, and Profiles in the PXF documentation for more information about the PXF profiles supported for Hadoop.

Both `gphdfs` and `pxf` utilize custom options in the `LOCATION` clause to identify data-format-, operation-, or profile-specific options supported by the protocol. For example, both `gphdfs` and `pxf` support parquet and compression options on `INSERT` operations.

Should you need to migrate a `gphdfs` writable external table that references an HDFS file to PXF, map `gphdfs` to PXF writable external table compression options as follows:

Description	gphdfs LOCATION Option	pxf LOCATION Option
Use of Compression	compress	Not applicable; depends on the profile - may be uncompressed by default or specified via COMPRESSION_CODEC
Type of compression	compression_type	COMPRESSION_TYPE
Compression codec	codec	COMPRESSION_CODEC
Level of Compression[1]	codec_level	CODEC_LEVEL (supported in PXF 5.14.0 and newer versions)

[1] Avro format `deflate` codec only.

If the HDFS file is a Parquet-format file, map these additional parquet options as follows:

Description	gphdfs LOCATION Option	pxf LOCATION Option
Parquet schema	schema	SCHEMA
Page size	pagesize	PAGE_SIZE
Row group size	rowgroupsize	ROWGROUP_SIZE
Parquet version	parquetversion *or* pqversion	PARQUET_VERSION
Enable a dictionary	dictionaryenable	The dictionary is always enabled when writing Parquet data with PXF
Dictionary page size	dictionarypagesize	DICTIONARY_PAGE_SIZE

Mapping the FORMAT Options

The `gphdfs` protocol uses the `FORMAT` clause to determine the format of the external data. For Avro- and Parquet-format data, the PXF `FORMAT` clause must identify the name of a custom formatter.

Data Format	gphdfs FORMAT Option	pxf FORMAT Option
Avro	FORMAT 'AVRO'	FORMAT 'CUSTOM' (FORMATTER='pxfwritable_import') (read) FORMAT 'CUSTOM' (FORMATTER='pxfwritable_export') (write)
Parquet	FORMAT 'PARQUET'	FORMAT 'CUSTOM' (FORMATTER='pxfwritable_import') (read) FORMAT 'CUSTOM' (FORMATTER='pxfwritable_export') (write)
Text	FORMAT 'TEXT' (DELIMITER ',')	FORMAT 'TEXT' (DELIMITER ',')

For text data, the `FORMAT` clause may identify a delimiter or other formatting option as described on the CREATE EXTERNAL TABLE command reference page.

Example gphdfs to pxf External Table Mapping for an HDFS Text File

Example `gphdfs` `CREATE EXTERNAL TABLE` command to read a text file on HDFS:

```
CREATE EXTERNAL TABLE ext_expenses (
        name text,
        date date,
        amount
float4,
        category text,
        desc1 text
)
   LOCATION ('gphdfs://hdfshost-1:8081/dir/filename.txt')
   FORMAT 'TEXT' (DELIMITER
',');
```

Equivalent `pxf` `CREATE EXTERNAL TABLE` command, providing that the `default` PXF server contains the Hadoop configuration:

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```
CREATE EXTERNAL TABLE ext_expenses_pxf (
        name text,
        date date,
        amount
float4,
        category text,
        desc1 text
)
   LOCATION ('pxf://dir/filename.txt?PROFILE=hdfs:text')
   FORMAT 'TEXT' (DELIMITER
',');
```

Verifying Access with PXF

Ensure that you can read from, or write to, each `pxf` external table that you have created.

Removing the gphdfs External Tables

You must remove all `gphdfs` external tables before you can successfully migrate a WarehousePG 4 or 5 database to WarehousePG 6.

Drop an external table as follows:

```
DROP EXTERNAL TABLE
<schema_name>.<external_table_name>;
```

Revoking Privileges to the gphdfs Protocol

Before you migrate, you must revoke privileges to the `gphdfs` protocol from each WarehousePG role to which you assigned the privileges.

Revoke the privilege as follows:

```
ALTER ROLE <role_name> NOCREATEEXTTABLE(protocol='gphdfs',type='readable');
ALTER ROLE <role_name> NOCREATEEXTTABLE(protocol='gphdfs',type='writable');
```

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9.1 PXF Upgrade and Migration

When you upgrade your WarehousePG cluster, you must perform some additional steps in order to bring your PXF configuration up to date.

1. *WarehousePG 6.x to 6.newer upgrade*: You may be required to perform PXF upgrade actions when you upgrade from a previous WarehousePG 6.x version. Note that different steps are outlined based on your PXF installation source: a manually installed `rpm` or `deb` or the PXF version included with the WarehousePG Server installer in versions 6.18.x and older.

If you are upgrading a PXF `rpm` or `deb` installation independent of a WarehousePG upgrade, refer to the PXF upgrade documentation.

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9.2 Upgrading PXF When You Upgrade from a Previous WarehousePG 6.x Version

> **Note: Note:** Starting in WarehousePG version 6.19.0, the PXF software is no longer bundled in the WarehousePG Server distribution. You may be required to download and install the PXF `rpm` or `deb` package to use PXF in your WarehousePG cluster as described in the procedures below.

If you are using PXF in your current WarehousePG 6.x installation, you must perform some PXF upgrade actions when you upgrade to a newer version of WarehousePG 6.x. This procedure uses*PXF.from* to refer to your currently-installed PXF version.

> **Note** if you are planning to upgrade a PXF `rpm` or `deb` installation, refer to the PXF upgrade documentation.

The PXF upgrade procedure has two parts. You perform one procedure before, and one procedure after, you upgrade to a new version of WarehousePG:

- Step 1: PXF Pre-Upgrade Actions
- Upgrade to a new WarehousePG version
- Step 2: Upgrading PXF

Step 1: PXF Pre-Upgrade Actions

Perform this procedure before you upgrade to a new version of WarehousePG:

1. Log in to the WarehousePG coordinator node. For example:

   ```
   $ ssh gpadmin@<gpcoordinator>
   ```

2. Identify and note the *PXF.from* version number. For example:

   ```
   gpadmin@gpcoordinator$ pxf version
   ```

3. Determine if *PXF.from* is a PXF `rpm` or `deb` installation (`/usr/local/pxf-gp<greenplum-major-version>`), or if you are running *PXF.from* from the WarehousePG server installation (`$GPHOME/pxf`), and note the answer.

4. If the *PXF.from* version is 5.x, identify the file system location of the `$PXF_CONF` setting in your PXF 5.x PXF installation; you might need this later. If you are unsure of the location, you can find the value in `pxf-env-default.sh` .

5. Stop PXF on each segment host as described in Stopping PXF.

6. Upgrade to the new version of WarehousePG and then continue your PXF upgrade with Step 2: Upgrading PXF.

Step 2: Registering or Upgrading PXF

After you upgrade to the new version of WarehousePG, perform the following procedure to configure the PXF software; you may be required to install the standalone PXF distribution:

1. Log in to the WarehousePG coordinator node. For example:

   ```
   $ ssh gpadmin@<gpcoordinator>
   ```

2. If you previously installed the PXF `rpm` or `deb` on your WarehousePG 6.x hosts, you must register it to continue using PXF:

   1. Copy the PXF extension files from the PXF installation directory to the new WarehousePG 6.x install directory:

      ```
      gpadmin@gpcoordinator pxf cluster register
      ```

   2. Start PXF on each segment host as described in Starting PXF.

   3. Skip the following steps and exit this procedure.

3. Starting in WarehousePG version 6.19.0, PXF is removed from the WarehousePG Server distribution. You must download and install the standalone PXF `rpm` or `deb` package as described in Installing PXF.

4. Synchronize the PXF configuration from the coordinator host to the standby coordinator and each WarehousePG segment host. For example:

   ```
   gpadmin@gpcoordinator$ $GPHOME/pxf/bin/pxf cluster sync
   ```

5. Start PXF on each segment host:

   ```
   gpadmin@gpcoordinator$ $GPHOME/pxf/bin/pxf cluster start
   ```

Your WarehousePG cluster is now running the same version of PXF, but running it from the PXF installation directory (`/usr/local/pxf-gp<greenplum-major-version>`). Should you wish to upgrade PXF in the future, consult the PXF upgrade documentation.

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