

Mastering PostgreSQL Administration

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POSTGRESQL is an open-source, full-featured relational database. This presentation covers advanced administration topics.

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Outline

1. Installation
2. Configuration
3. Maintenance
4. Monitoring
5. Recovery

1. Installation

- Click-through Installers
 - MS Windows
 - Linux
 - OS X
- Ports
 - RPM
 - DEB
 - PKG
 - other packages
- Source
 - obtaining
 - build options
 - installing

Initialization (initdb)

```
$ initdb /u/pgsql/data
```

The files belonging to this database system will be owned by user "postgres".
This user must also own the server process.

The database cluster will be initialized with locale "en_US.UTF-8".
The default database encoding has accordingly been set to "UTF8".
The default text search configuration will be set to "english".

Data page checksums are disabled.

```
fixing permissions on existing directory /u/pgsql/data ... ok
creating subdirectories ... ok
selecting default max_connections ... 100
selecting default shared_buffers ... 128MB
selecting dynamic shared memory implementation ... posix
creating configuration files ... ok
running bootstrap script ... ok
performing post-bootstrap initialization ... ok
syncing data to disk ... ok
```

WARNING: enabling "trust" authentication for local connections
You can change this by editing pg_hba.conf or using the option -A, or
--auth-local and --auth-host, the next time you run initdb.

Success. You can now start the database server using:

```
pg_ctl -D /u/pgsql/data -l logfile start
```

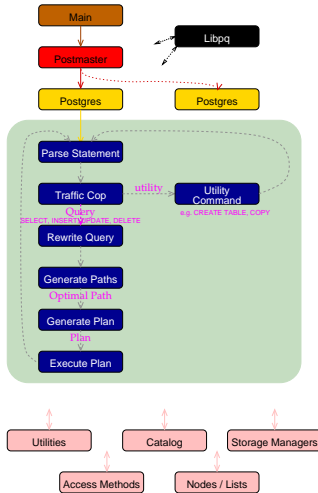
pg_controldata

\$ pg_controldata

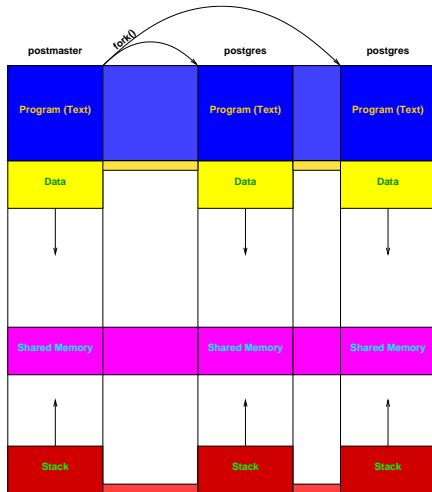
```
pg_control version number:      1002
Catalog version number:        201707211
Database system identifier:     6544633619067825437
Database cluster state:        shut down
pg_control last modified:       Sun 15 Apr 2018 07:20:58 AM EDT
Latest checkpoint location:     0/15C09E0
Prior checkpoint location:      0/15C0708
Latest checkpoint's REDO location: 0/15C09E0
Latest checkpoint's REDO WAL file: 00000001000000000000000001
Latest checkpoint's TimeLineID: 1
Latest checkpoint's PrevTimeLineID: 1
Latest checkpoint's full_page_writes: on
Latest checkpoint's NextXID:    0:555
Latest checkpoint's NextOID:    12296
Latest checkpoint's NextMultiXactId: 1
Latest checkpoint's NextMultiOffset: 0
Latest checkpoint's oldestXID:   548
Latest checkpoint's oldestXID's DB: 1
Latest checkpoint's oldestActiveXID: 0
Latest checkpoint's oldestMultiXid: 1
Latest checkpoint's oldestMulti's DB: 1
Latest checkpoint's oldestCommitTsXid: 0
Latest checkpoint's newestCommitTsXid: 0
Time of latest checkpoint:      Sun 15 Apr 2018 07:20:58 AM EDT
Fake LSN counter for unlogged rels: 0/1
Minimum recovery ending location: 0/0
Min recovery ending loc's timeline: 0
Backup start location:          0/0
Backup end location:            0/0
```

...

System Architecture



Session Creation



Starting Postmaster

```
2018-04-15 07:23:18.172 EDT [12055] LOG:  listening on IPv4 address "127.0.0.1", port 5432
2018-04-15 07:23:18.173 EDT [12055] LOG:  listening on Unix socket "/tmp/.s.PGSQL.5432"
2018-04-15 07:23:18.185 EDT [12056] LOG:  database system was shut down at 2018-04-15 07:22:54 EDT
2018-04-15 07:23:18.188 EDT [12055] LOG:  database system is ready to accept connections
```

- manually
- pg_ctl start
- on boot

Stopping Postmaster

```
2018-04-15 07:23:47.317 EDT [12055] LOG:  received fast shutdown request
2018-04-15 07:23:47.318 EDT [12055] LOG:  aborting any active transactions
2018-04-15 07:23:47.318 EDT [12055] LOG:  worker process: logical replication launcher (PID 12062) exited with exit code 1
2018-04-15 07:23:47.319 EDT [12057] LOG:  shutting down
2018-04-15 07:23:47.327 EDT [12055] LOG:  database system is shut down
```

- manually
- `pg_ctl stop`
- on shutdown

Connections

- local — unix domain socket
- host — TCP/IP, both SSL or non-SSL
- hostssl — only SSL
- hostnossll — never SSL

Authentication

- trust
- reject
- passwords
 - scram-sha-256
 - md5
 - password (cleartext)
- local authentication
 - socket permissions
 - 'peer' socket user name passing
 - host ident using local identd

Authentication (continued)

- remote authentication
 - host ident using pg_ident.conf
 - kerberos
 - gss
 - sspi
 - pam
 - ldap
 - radius
 - cert

- hostname and network mask
- database name
- role name (user or group)
- filename or list of databases, role
- IPv6

pg_hba.conf Default

#	TYPE	DATABASE	USER	ADDRESS	METHOD
# "local" is for Unix domain socket connections only					
local	all		all		trust
# IPv4 local connections:					
host	all		all	127.0.0.1/32	trust
# IPv6 local connections:					
host	all		all	::1/128	trust
# Allow replication connections from localhost, by a user with the					
# replication privilege.					
#local	replication		postgres		trust
#host	replication		postgres	127.0.0.1/32	trust
#host	replication		postgres	::1/128	trust

pg_hba.conf Example

#	TYPE	DATABASE	USER	ADDRESS	METHOD
# "local" is for Unix domain socket connections only					
local	all		all		trust
# IPv4 local connections:					
host	all		all	127.0.0.1/32	trust
# IPv6 local connections:					
host	all		all	::1/128	trust
# disable connections from the gateway machine					
host	all		all	192.168.1.254/32	reject
# enable local network					
host	all		all	192.168.1.0/24	scram-sha-256
# require SSL for external connections, but do not allow the superuser					
hostssl	all		postgres	0.0.0.0/0	reject
hostssl	all		all	0.0.0.0/0	scram-sha-256

Permissions

- Host connection permissions
- Role permissions
 - create roles
 - create databases
 - table permissions
- Database management
 - template1 customization
 - system tables
 - disk space computations

Data Directory

```
$ ls -CF
```

```
base/          pg_ident.conf  pg_serial/     pg_tblspc/     postgresql.auto.conf
global/        pg_logical/    pg_snapshots/  pg_twophase/    postgresql.conf
pg_commit_ts/  pg_multixact/  pg_stat/       PG_VERSION      postmaster.opts
pg_dynshmem/   pg_notify/     pg_stat_tmp/   pg_wal/
pg_hba.conf    pg_replslot/   pg_subtrans/   pg_xact/
```

Database Directories

```
$ ls -CF global/
```

1136	1214_fsm	1261_vm	2671	2846	2967	6000_vm
1136_fsm	1214_vm	1262	2672	2846_vm	3592	6001
1136_vm	1232	1262_fsm	2676	2847	3592_vm	6002
1137	1233	1262_vm	2677	2964	3593	pg_control
1213	1260	2396	2694	2964_vm	4060	pg_filenode.map
1213_fsm	1260_fsm	2396_fsm	2695	2965	4060_vm	pg_internal.init
1213_vm	1260_vm	2396_vm	2697	2966	4061	
1214	1261	2397	2698	2966_vm	6000	

```
$ ls -CF base/
```

```
1/ 12406/ 12407/ 16384/
```

```
$ ls -CF base/16384
```

112	1249_fsm	2606_vm	2652	2699	3081	3598_vm
113	1249_vm	2607	2653	2701	3085	3599
12242	1255	2607_fsm	2654	2702	3118	3600
12242_fsm	1255_fsm	2607_vm	2655	2703	3118_vm	3600_fsm
12242_vm	1255_vm	2608	2656	2704	3119	3600_vm
12244	1259	2608_fsm	2657	2753	3164	3601
12246	1259_fsm	2608_vm	2658	2753_fsm	3256	3601_fsm

```
...
```

Transaction/WAL Directories

```
$ ls -CF pg_wal/  
00000001000000000000000001 archive_status/
```

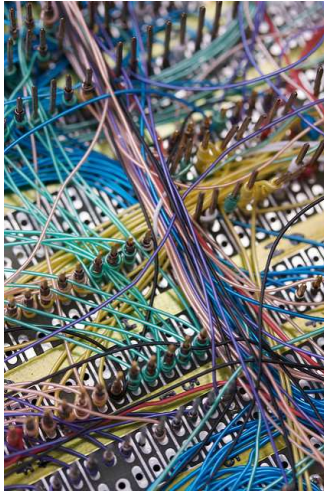
```
$ ls -CF pg_xact/  
0000
```

Configuration Directories

```
$ ls -CF share/
```

conversion_create.sql	postgres.bki	snowball_create.sql
extension/	postgres.description	sql_features.txt
information_schema.sql	postgresql.conf.sample	system_views.sql
pg_hba.conf.sample	postgres.shdescription	timezone/
pg_ident.conf.sample	psqlrc.sample	timezonesets/
pg_service.conf.sample	recovery.conf.sample	tsearch_data/

2. Configuration



<https://www.flickr.com/photos/mwichary/>

postgresql.conf

```
# -----  
# PostgreSQL configuration file  
# -----  
#  
# This file consists of lines of the form:  
#  
#   name = value  
#  
# (The "=" is optional.)  Whitespace may be used.  Comments are introduced with  
# "#" anywhere on a line.  The complete list of parameter names and allowed  
# values can be found in the PostgreSQL documentation.  
#  
# The commented-out settings shown in this file represent the default values.  
# Re-commenting a setting is NOT sufficient to revert it to the default value;  
# you need to reload the server.
```

postgresql.conf (Continued)

```
# This file is read on server startup and when the server receives a SIGHUP
# signal.  If you edit the file on a running system, you have to SIGHUP the
# server for the changes to take effect, run "pg_ctl reload", or execute
# "SELECT pg_reload_conf()".  Some parameters, which are marked below,
# require a server shutdown and restart to take effect.
#
# Any parameter can also be given as a command-line option to the server, e.g.,
# "postgres -c log_connections=on".  Some parameters can be changed at run time
# with the "SET" SQL command.
#
# Memory units:  kB = kilobytes           Time units:  ms  = milliseconds
#                MB  = megabytes           s    = seconds
#                GB  = gigabytes           min = minutes
#                TB  = terabytes           h    = hours
#                                           d    = days
```

Configuration File Location

```
# The default values of these variables are driven from the -D command-line  
# option or PGDATA environment variable, represented here as ConfigDir.
```

```
#data_directory = 'ConfigDir'          # use data in another directory  
                                         # (change requires restart)  
#hba_file = 'ConfigDir/pg_hba.conf'    # host-based authentication file  
                                         # (change requires restart)  
#ident_file = 'ConfigDir/pg_ident.conf' # ident configuration file  
                                         # (change requires restart)
```

```
# If external_pid_file is not explicitly set, no extra PID file is written.  
#external_pid_file = ''                # write an extra PID file  
                                         # (change requires restart)
```


Connections and Authentication

```
#listen_addresses = 'localhost'      # what IP address(es) to listen on;
                                      # comma-separated list of addresses;
                                      # defaults to 'localhost'; use '*' for all
                                      # (change requires restart)
#port = 5432                          # (change requires restart)
max_connections = 100                 # (change requires restart)
#superuser_reserved_connections = 3   # (change requires restart)
#unix_socket_directories = '/tmp'     # comma-separated list of directories
                                      # (change requires restart)
#unix_socket_group = ''               # (change requires restart)
#unix_socket_permissions = 0777      # begin with 0 to use octal notation
                                      # (change requires restart)
#bonjour = off                        # advertise server via Bonjour
                                      # (change requires restart)
#bonjour_name = ''                   # defaults to the computer name
                                      # (change requires restart)
```

Security and Authentication

```
#authentication_timeout = 1min          # 1s-600s
#ssl = off
#ssl_ciphers = 'HIGH:MEDIUM:+3DES:!aNULL' # allowed SSL ciphers
#ssl_prefer_server_ciphers = on
#ssl_ecdh_curve = 'prime256v1'
#ssl_dh_params_file = ''
#ssl_cert_file = 'server.crt'
#ssl_key_file = 'server.key'
#ssl_ca_file = ''
#ssl_crl_file = ''
#password_encryption = md5              # md5 or scram-sha-256
#db_user_namespace = off
#row_security = on

# GSSAPI using Kerberos
#krb_server_keyfile = ''
#krb_caseins_users = off
```

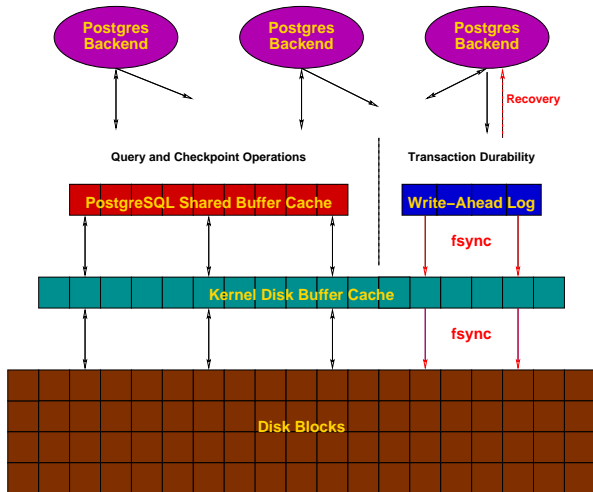
TCP/IP Control

```
#tcp_keepalives_idle = 0          # TCP_KEEPIDLE, in seconds;  
                                   # 0 selects the system default  
#tcp_keepalives_interval = 0     # TCP_KEEPINTVL, in seconds;  
                                   # 0 selects the system default  
#tcp_keepalives_count = 0        # TCP_KEEPCNT;
```

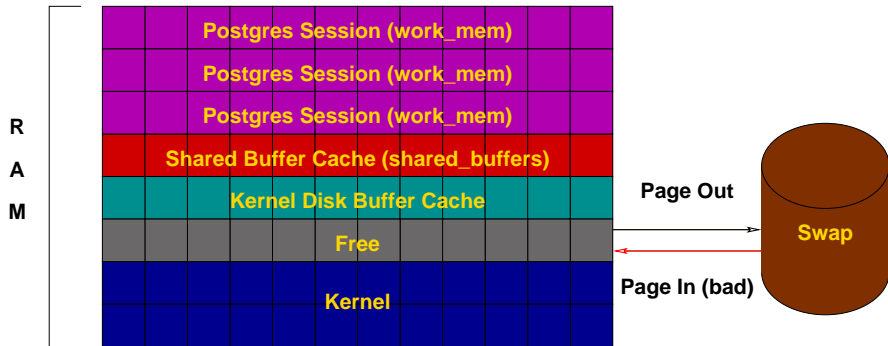
Memory Usage

```
shared_buffers = 128MB          # min 128kB
                                # (change requires restart)
#huge_pages = try               # on, off, or try
                                # (change requires restart)
#temp_buffers = 8MB             # min 800kB
#max_prepared_transactions = 0  # zero disables the feature
                                # (change requires restart)
# Caution: it is not advisable to set max_prepared_transactions nonzero unless
# you actively intend to use prepared transactions.
#work_mem = 4MB                 # min 64kB
#maintenance_work_mem = 64MB   # min 1MB
#replacement_sort_tuples = 150000 # limits use of replacement selection sort
#autovacuum_work_mem = -1       # min 1MB, or -1 to use maintenance_work_mem
#max_stack_depth = 2MB          # min 100kB
dynamic_shared_memory_type = posix # the default is the first option
                                   # supported by the operating system:
                                   #   posix
                                   #   sysv
                                   #   windows
                                   #   mmap
                                   # use none to disable dynamic shared memory
                                   # (change requires restart)
```

Memory Usage (Continued)



Sizing Shared Memory



Disk and Kernel Resources

- Disk -

```
#temp_file_limit = -1          # limits per-process temp file space  
                                # in kB, or -1 for no limit
```

- Kernel Resource Usage -

```
#max_files_per_process = 1000  # min 25  
                                # (change requires restart)  
#shared_preload_libraries = '' # (change requires restart)
```

Vacuum and Background Writer

- Cost-Based Vacuum Delay -

#vacuum_cost_delay = 0	# 0-100 milliseconds
#vacuum_cost_page_hit = 1	# 0-10000 credits
#vacuum_cost_page_miss = 10	# 0-10000 credits
#vacuum_cost_page_dirty = 20	# 0-10000 credits
#vacuum_cost_limit = 200	# 1-10000 credits

- Background Writer -

#bgwriter_delay = 200ms	# 10-10000ms between rounds
#bgwriter_lru_maxpages = 100	# 0-1000 max buffers written/round
#bgwriter_lru_multiplier = 2.0	# 0-10.0 multiplier on buffers scanned/round
#bgwriter_flush_after = 512kB	# measured in pages, 0 disables

Asynchronous Behavior

- Asynchronous Behavior -

#effective_io_concurrency = 1	# 1-1000; 0 disables prefetching
#max_worker_processes = 8	# (change requires restart)
#max_parallel_workers_per_gather = 2	# taken from max_parallel_workers
#max_parallel_workers = 8	# maximum number of max_worker_processes that # can be used in parallel queries
#old_snapshot_threshold = -1	# 1min-60d; -1 disables; 0 is immediate # (change requires restart)
#backend_flush_after = 0	# measured in pages, 0 disables

Write-Ahead Log (WAL)

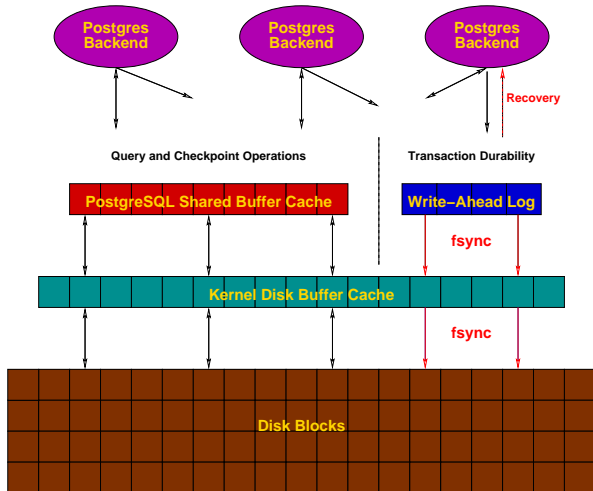
```
#wal_level = replica
#fsync = on
#synchronous_commit = on
#wal_sync_method = fsync

# minimal, replica, or logical
# (change requires restart)
# flush data to disk for crash safety
# (turning this off can cause
# unrecoverable data corruption)
# synchronization level;
# off, local, remote_write, remote_apply, or on
# the default is the first option
# supported by the operating system:
#   open_datasync
#   fdatasync (default on Linux)
#   fsync
#   fsync_writethrough
#   open_sync
```

Write-Ahead Log (WAL)

<code>#full_page_writes = on</code>	<code># recover from partial page writes</code>
<code>#wal_compression = off</code>	<code># enable compression of full-page writes</code>
<code>#wal_log_hints = off</code>	<code># also do full page writes of non-critical updates</code>
	<code># (change requires restart)</code>
<code>#wal_buffers = -1</code>	<code># min 32kB, -1 sets based on shared_buffers</code>
	<code># (change requires restart)</code>
<code>#wal_writer_delay = 200ms</code>	<code># 1-10000 milliseconds</code>
<code>#wal_writer_flush_after = 1MB</code>	<code># measured in pages, 0 disables</code>
<code>#commit_delay = 0</code>	<code># range 0-100000, in microseconds</code>
<code>#commit_siblings = 5</code>	<code># range 1-1000</code>

Write-Ahead Logging (Continued)



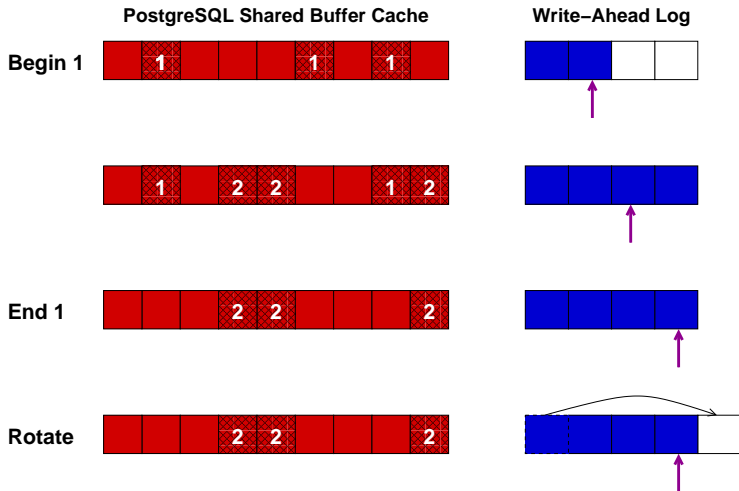
Checkpoints and Archiving

```
#checkpoint_timeout = 5min           # range 30s-1d
#max_wal_size = 1GB
#min_wal_size = 80MB
#checkpoint_completion_target = 0.5   # checkpoint target duration, 0.0 - 1.0
#checkpoint_flush_after = 256kB        # measured in pages, 0 disables
#checkpoint_warning = 30s              # 0 disables

# - Archiving -

#archive_mode = off                   # enables archiving; off, on, or always
#                                     # (change requires restart)
#archive_command = ''                 # command to use to archive a logfile segment
#                                     # placeholders: %p = path of file to archive
#                                     #                                     %f = file name only
#                                     # e.g., 'test ! -f /mnt/server/archivedir/%f && cp %p ...
#archive_timeout = 0                  # force a logfile segment switch after this
#                                     # number of seconds; 0 disables
```

Write-Ahead Logging (Continued)



Sending Server

Set these on the master and on any standby that will send replication data.

```
#max_wal_senders = 10          # max number of walsender processes
                                # (change requires restart)
#wal_keep_segments = 0        # in logfile segments, 16MB each; 0 disables
#wal_sender_timeout = 60s     # in milliseconds; 0 disables

#max_replication_slots = 10   # max number of replication slots
                                # (change requires restart)
#track_commit_timestamp = off # collect timestamp of transaction commit
                                # (change requires restart)
```

Primary Replication Server

```
# These settings are ignored on a standby server.  
  
#synchronous_standby_names = '' # standby servers that provide sync rep  
                                # method to choose sync standbys, number of sync standbys,  
                                # and comma-separated list of application_name  
                                # from standby(s); '*' = all  
#vacuum_defer_cleanup_age = 0  # number of xacts by which cleanup is delayed
```


Standby Replication Server

These settings are ignored on a master server.

#hot_standby = on	# "off" disallows queries during recovery # (change requires restart)
#max_standby_archive_delay = 30s	# max delay before canceling queries # (change requires restart)
#fsync = on	# flush data to disk for crash safety # (turning this off can cause # unrecoverable data corruption)
#synchronous_commit = on	# synchronization level; # off, local, remote_write, remote_apply, or on
#wal_sync_method = fsync	# the default is the first option # supported by the operating system: # open_datasync # fdatasync (default on Linux) # fsync # fsync_writethrough # open_sync # when reading WAL from archive; # -1 allows indefinite delay

Standby Replication Server

<code>#max_standby_streaming_delay = 30s</code>	<code># max delay before canceling queries</code> <code># when reading streaming WAL;</code> <code># -1 allows indefinite delay</code>
<code>#wal_receiver_status_interval = 10s</code>	<code># send replies at least this often</code> <code># 0 disables</code>
<code>#hot_standby_feedback = off</code>	<code># send info from standby to prevent</code> <code># query conflicts</code>
<code>#wal_receiver_timeout = 60s</code>	<code># time that receiver waits for</code> <code># communication from master</code> <code># in milliseconds; 0 disables</code>
<code>#wal_retrieve_retry_interval = 5s</code>	<code># time to wait before retrying to</code> <code># retrieve WAL after a failed attempt</code>

Subscriber Server

```
# These settings are ignored on a publisher.
```

[illegible]

```
#max_sync_workers_per_subscription = 2 # taken from max_logical_replication_workers
```

Planner Method Tuning

```
#enable_bitmapscan = on  
#enable_hashagg = on  
#enable_hashjoin = on  
#enable_indexscan = on  
#enable_indexonlyscan = on  
#enable_material = on  
#enable_mergejoin = on  
#enable_nestloop = on  
#enable_seqscan = on  
#enable_sort = on  
#enable_tidscan = on
```

Planner Constants

```
#seq_page_cost = 1.0           # measured on an arbitrary scale
#random_page_cost = 4.0        # same scale as above
#cpu_tuple_cost = 0.01         # same scale as above
#cpu_index_tuple_cost = 0.005  # same scale as above
#cpu_operator_cost = 0.0025    # same scale as above
#parallel_tuple_cost = 0.1     # same scale as above
#parallel_setup_cost = 1000.0  # same scale as above
#min_parallel_table_scan_size = 8MB
#min_parallel_index_scan_size = 512kB
#effective_cache_size = 4GB
```

Planner GEQO

```
#geqo = on
#geqo_threshold = 12
#geqo_effort = 5
#geqo_pool_size = 0
#geqo_generations = 0
#geqo_selection_bias = 2.0
#geqo_seed = 0.0
```

range 1-10
selects default based on effort
selects default based on effort
range 1.5-2.0
range 0.0-1.0

Miscellaneous Planner Options

<code>#default_statistics_target = 100</code>	<code># range 1-10000</code>
<code>#constraint_exclusion = partition</code>	<code># on, off, or partition</code>
<code>#cursor_tuple_fraction = 0.1</code>	<code># range 0.0-1.0</code>
<code>#from_collapse_limit = 8</code>	
<code>#join_collapse_limit = 8</code>	<code># 1 disables collapsing of explicit</code>
	<code># JOIN clauses</code>
<code>#force_parallel_mode = off</code>	

Where To Log

```
#log_destination = 'stderr'          # Valid values are combinations of
                                     # stderr, csvlog, syslog, and eventlog,
                                     # depending on platform.  csvlog
                                     # requires logging_collector to be on.

# This is used when logging to stderr:
#logging_collector = off              # Enable capturing of stderr and csvlog
                                     # into log files. Required to be on for
                                     # csvlogs.
                                     # (change requires restart)

# These are only used if logging_collector is on:
#log_directory = 'log'                # directory where log files are written,
                                     # can be absolute or relative to PGDATA
#log_filename = 'postgresql-%Y-%m-%d_%H%M%S.log'  # log file name pattern,
                                     # can include strftime() escapes
#log_file_mode = 0600                # creation mode for log files,
                                     # begin with 0 to use octal notation
```


Where To Log (rotation)

```
#log_truncate_on_rotation = off
```

```
# If on, an existing log file with the  
# same name as the new log file will be  
# truncated rather than appended to.  
# But such truncation only occurs on  
# time-driven rotation, not on restarts  
# or size-driven rotation. Default is  
# off, meaning append to existing files  
# in all cases.
```

```
#log_rotation_age = 1d
```

```
# Automatic rotation of logfiles will  
# happen after that time. 0 disables.
```

```
#log_rotation_size = 10MB
```

```
# Automatic rotation of logfiles will  
# happen after that much log output.  
# 0 disables.
```

Where to Log (syslog)

```
#syslog_facility = 'LOCAL0'
#syslog_ident = 'postgres'
#syslog_sequence_numbers = on
#syslog_split_messages = on

# This is only relevant when logging to eventlog (win32):
# (change requires restart)
#event_source = 'PostgreSQL'
```

When to Log

```
#client_min_messages = notice
```

```
# values in order of decreasing detail:
```

```
# debug5
```

```
# debug4
```

```
# debug3
```

```
# debug2
```

```
# debug1
```

```
# log
```

```
# notice
```

```
# warning
```

```
# error
```

```
#log_min_messages = warning
```

```
# values in order of decreasing detail:
```

```
# debug5
```

```
# debug4
```

```
# debug3
```

```
# debug2
```

```
# debug1
```

```
# info
```

```
# notice
```

```
# warning
```

```
# error
```

```
# log
```

```
# fatal
```

```
# panic
```

When to Log (Continued)

```
#log_min_error_statement = error      # values in order of decreasing detail:
#                                     #   debug5
#                                     #   debug4
#                                     #   debug3
#                                     #   debug2
#                                     #   debug1
#                                     #   info
#                                     #   notice
#                                     #   warning
#                                     #   error
#                                     #   log
#                                     #   fatal
#                                     #   panic (effectively off)

#log_min_duration_statement = -1      # -1 is disabled, 0 logs all statements
#                                     # and their durations, > 0 logs only
#                                     # statements running at least this number
#                                     # of milliseconds
```

What to Log

```
#debug_print_parse = off
#debug_print_rewritten = off
#debug_print_plan = off
#debug_pretty_print = on
#log_checkpoints = off
#log_connections = off
#log_disconnections = off
#log_duration = off
#log_error_verbosity = default      # terse, default, or verbose messages
#log_hostname = off
```

What To Log: Log_line_prefix

```
#log_line_prefix = '%m [%p] '
```

```
# special values:
```

```
# %a = application name
```

```
# %u = user name
```

```
# %d = database name
```

```
# %r = remote host and port
```

```
# %h = remote host
```

```
# %p = process ID
```

```
# %t = timestamp without milliseconds
```

```
# %m = timestamp with milliseconds
```

```
# %n = timestamp with milliseconds (as a Unix epoch)
```

```
# %i = command tag
```

```
# %e = SQL state
```

```
# %c = session ID
```

```
# %l = session line number
```

```
# %s = session start timestamp
```

```
# %v = virtual transaction ID
```

```
# %x = transaction ID (0 if none)
```

```
# %q = stop here in non-session
```

```
# processes
```

```
# %% = '%'
```

```
# e.g., '<%u%%d> '
```

What to Log (Continued)

```
#log_lock_waits = off  
#log_statement = 'none'  
#log_replication_commands = off  
#log_temp_files = -1
```

```
log_timezone = 'US/Eastern'
```

```
# - Process Title -
```

```
#cluster_name = ''
```

```
#update_process_title = on
```

```
# log lock waits >= deadlock_timeout  
# none, ddl, mod, all
```

```
# log temporary files equal or larger  
# than the specified size in kilobytes;  
# -1 disables, 0 logs all temp files
```

```
# added to process titles if nonempty  
# (change requires restart)
```

Runtime Statistics

- Query/Index Statistics Collector -

#track_activities = on

#track_counts = on

#track_io_timing = off

#track_functions = none # none, pl, all

#track_activity_query_size = 1024 # (change requires restart)

#stats_temp_directory = 'pg_stat_tmp'

- Statistics Monitoring -

#log_parser_stats = off

#log_planner_stats = off

#log_executor_stats = off

#log_statement_stats = off

Autovacuum

<code>#autovacuum = on</code>	<code># Enable autovacuum subprocess? 'on'</code>
<code>#log_autovacuum_min_duration = -1</code>	<code># requires track_counts to also be on.</code>
	<code># -1 disables, 0 logs all actions and</code>
	<code># their durations, > 0 logs only</code>
	<code># actions running at least this number</code>
	<code># of milliseconds.</code>
<code>#autovacuum_max_workers = 3</code>	<code># max number of autovacuum subprocesses</code>
	<code># (change requires restart)</code>
<code>#autovacuum_naptime = 1min</code>	<code># time between autovacuum runs</code>
<code>#autovacuum_vacuum_threshold = 50</code>	<code># min number of row updates before</code>
	<code># vacuum</code>
<code>#autovacuum_analyze_threshold = 50</code>	<code># min number of row updates before</code>
	<code># analyze</code>

Autovacuum

```
#autovacuum_vacuum_scale_factor = 0.2    # fraction of table size before vacuum
#autovacuum_analyze_scale_factor = 0.1    # fraction of table size before analyze
#autovacuum_freeze_max_age = 200000000    # maximum XID age before forced vacuum
#                                         # (change requires restart)
#autovacuum_multixact_freeze_max_age = 400000000    # maximum multixact age
#                                         # before forced vacuum
#                                         # (change requires restart)
#autovacuum_vacuum_cost_delay = 20ms    # default vacuum cost delay for
#                                         # autovacuum, in milliseconds;
#                                         # -1 means use vacuum_cost_delay
#autovacuum_vacuum_cost_limit = -1    # default vacuum cost limit for
#                                         # autovacuum, -1 means use
#                                         # vacuum_cost_limit
```

Statement Behavior

```
#search_path = '$user', public'      # schema names
#default_tablespace = ''             # a tablespace name, '' uses the default
#temp_tablespaces = ''               # a list of tablespace names, '' uses
                                      # only default tablespace

#check_function_bodies = on
#default_transaction_isolation = 'read committed'
#default_transaction_read_only = off
#default_transaction_deferrable = off
#session_replication_role = 'origin'
#statement_timeout = 0                # in milliseconds, 0 is disabled
#lock_timeout = 0                    # in milliseconds, 0 is disabled
#idle_in_transaction_session_timeout = 0 # in milliseconds, 0 is disabled
#vacuum_freeze_min_age = 500000000
#vacuum_freeze_table_age = 1500000000
#vacuum_multixact_freeze_min_age = 50000000
#vacuum_multixact_freeze_table_age = 1500000000
#bytea_output = 'hex'                # hex, escape
#xmlbinary = 'base64'
#xmloption = 'content'
#gin_fuzzy_search_limit = 0
#gin_pending_list_limit = 4MB
```

Locale, Formatting, and Full Text Search

```
datestyle = 'iso, mdy'
#intervalstyle = 'postgres'
timezone = 'US/Eastern'
#timezone_abbreviations = 'Default'      # Select the set of available time zone
                                         # abbreviations. Currently, there are
                                         #   Default
                                         #   Australia (historical usage)
                                         #   India
                                         # You can create your own file in
                                         # share/timezonesets/.
#extra_float_digits = 0                  # min -15, max 3
#client_encoding = sql_ascii             # actually, defaults to database
                                         # encoding

# These settings are initialized by initdb, but they can be changed.
lc_messages = 'en_US.UTF-8'              # locale for system error message
                                         # strings
lc_monetary = 'en_US.UTF-8'              # locale for monetary formatting
lc_numeric = 'en_US.UTF-8'               # locale for number formatting
lc_time = 'en_US.UTF-8'                  # locale for time formatting
# default configuration for text search
default_text_search_config = 'pg_catalog.english'
```

Other Defaults

```
#dynamic_library_path = '$libdir'  
#local_preload_libraries = ''  
#session_preload_libraries = ''
```

Lock Management

```
#deadlock_timeout = 1s
#max_locks_per_transaction = 64      # min 10
                                      # (change requires restart)
#max_pred_locks_per_transaction = 64 # min 10
                                      # (change requires restart)
#max_pred_locks_per_relation = -2    # negative values mean
                                      # (max_pred_locks_per_transaction
                                      # / -max_pred_locks_per_relation) - 1
#max_pred_locks_per_page = 2         # min 0
```

Version/Platform Compatibility

- Previous PostgreSQL Versions -

```
#array_nulls = on
#backslash_quote = safe_encoding      # on, off, or safe_encoding
#default_with_oids = off
#escape_string_warning = on
#lo_compat_privileges = off
#operator_precedence_warning = off
#quote_all_identifiers = off
#standard_conforming_strings = on
#synchronize_seqscans = on
```

- Other Platforms and Clients -

```
#transform_null_equals = off
```

Error Handling

```
#exit_on_error = off  
#restart_after_crash = on
```

```
# terminate session on any error?  
# reinitialize after backend crash?
```


Config File Includes

```
#include_dir = 'conf.d'           # include files ending in '.conf' from  
                                  # directory 'conf.d'  
#include_if_exists = 'exists.conf' # include file only if it exists  
#include = 'special.conf'         # include file
```

Interfaces

- Installing
 - Compiled Languages (C, ecpg)
 - Scripting Language (Perl, Python, PHP)
 - SPI
- Connection Pooling

Include Files

```
$ ls -CF include/
```

ecpg_config.h	libpq/	pgtypes_date.h	sql3types.h
ecpgerrno.h	libpq-events.h	pgtypes_error.h	sqlca.h
ecpg_informix.h	libpq-fe.h	pgtypes_interval.h	sqlda-compat.h
ecpglib.h	pg_config_ext.h	pgtypes_numeric.h	sqlda.h
ecpgtype.h	pg_config.h	pgtypes_timestamp.h	sqlda-native.h
informix/	pg_config_manual.h	postgres_ext.h	
internal/	pg_config_os.h	server/	

Library Files

```
$ ls -CF lib/
```

ascii_and_mic.so*	libpgcommon.a	utf8_and_ascii.so*
cyrillic_and_mic.so*	libpgfeutils.a	utf8_and_big5.so*
dict_snowball.so*	libpgport.a	utf8_and_cyrillic.so*
euc2004_sjis2004.so*	libpgtypes.a	utf8_and_euc2004.so*
euc_cn_and_mic.so*	libpgtypes.so@	utf8_and_euc_cn.so*
euc_jp_and_sjis.so*	libpgtypes.so.3@	utf8_and_euc_jp.so*
euc_kr_and_mic.so*	libpgtypes.so.3.10*	utf8_and_euc_kr.so*
euc_tw_and_big5.so*	libpq.a	utf8_and_euc_tw.so*
latin2_and_win1250.so*	libpq.so@	utf8_and_gb18030.so*
latin_and_mic.so*	libpq.so.5@	utf8_and_gbk.so*
libecpg.a	libpq.so.5.10*	utf8_and_iso8859_1.so*
libecpg_compat.a	libpqwalreceiver.so*	utf8_and_iso8859.so*
libecpg_compat.so@	pgoutput.so*	utf8_and_johab.so*
libecpg_compat.so.3@	pgxs/	utf8_and_sjis2004.so*
libecpg_compat.so.3.10*	pkgconfig/	utf8_and_sjis.so*
libecpg.so@	plperl.so*	utf8_and_uhc.so*
libecpg.so.6@	plpgsql.so*	utf8_and_win.so*
libecpg.so.6.10*	plpython2.so*	

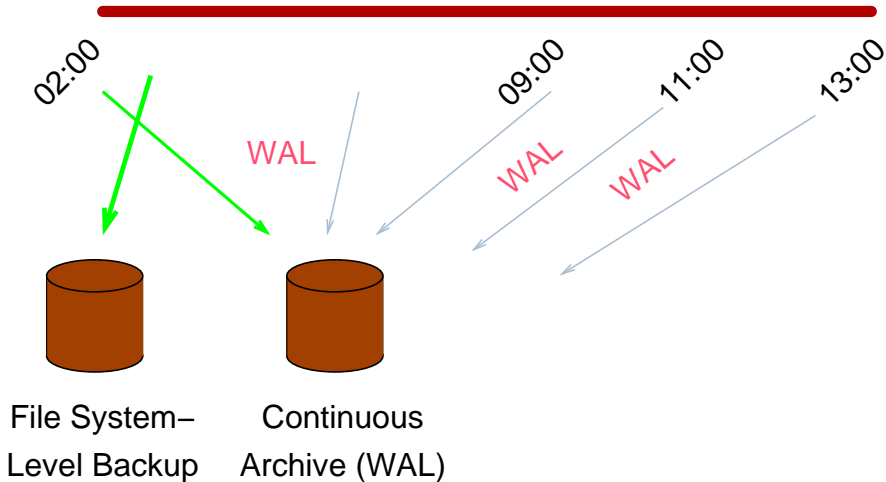
3. Maintenance



Backup

- File system-level (physical)
 - tar, cpio while shutdown
 - file system snapshot
 - rsync, shutdown, rsync, restart
- pg_dump/pg_dumpall (logical)
- Restore/pg_restore with custom format

Continuous Archiving / Point-In-Time Recovery (PITR)

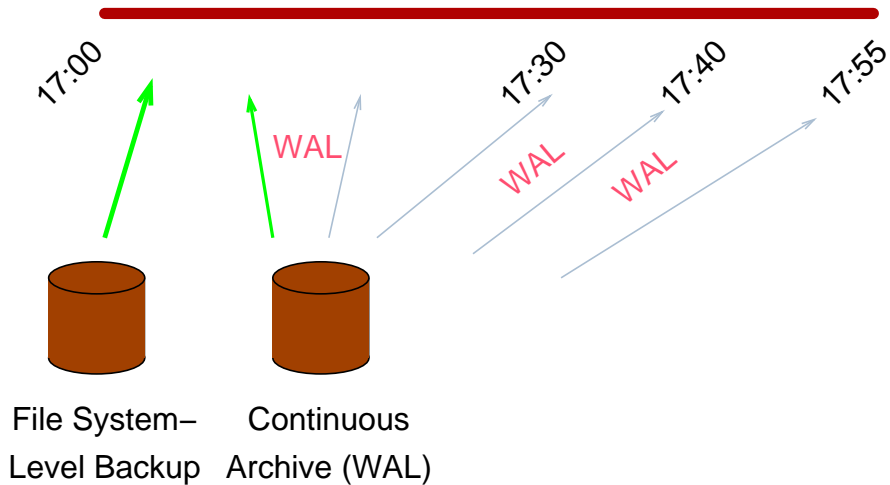


PITR Backup Procedures

1. `archive_mode = on`
2. `wal_level = archive`
3. `archive_command = 'cp -i %p /mnt/server/pgsql/%f < /dev/null'`
4. `SELECT pg_start_backup('label');`
5. Perform file system-level backup (can be inconsistent)
6. `SELECT pg_stop_backup();`

pg_basebackup does this automatically.

PITR Recovery



PITR Recovery Procedures

1. Stop postmaster
2. Restore file system-level backup
3. Make adjustments as outlined in the documentation
4. Create recovery.conf
5. `restore_command = 'cp /mnt/server/pgsql/%f %p'`
6. Start the postmaster

Continuous Archive Management

Simplify backups and WAL archive file management with:

- *pgBackRest*
- *barman*

Data Maintenance

- VACUUM (nonblocking) records free space into .fsm (free space map) files
- ANALYZE collects optimizer statistics
- VACUUM FULL (blocking) shrinks the size of database disk files

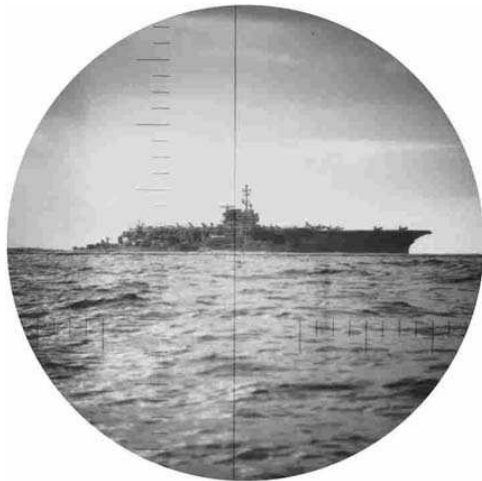
Automating Tasks

Autovacuum handles vacuum and analyze tasks automatically.

Checkpoints

- Write all dirty shared buffers
- Sync all dirty kernel buffers
- Recycle WAL files
- Controlled by *checkpoint_timeout* and *max_wal_size*

4. Monitoring



```
$ ps -f -Upostgres
```

postgres	825	1	0	Tue12AM	??	0:06.57	/u/pgsql/bin/postmaster -i
postgres	829	825	0	Tue12AM	??	0:35.03	writer process (postmaster)
postgres	830	825	0	Tue12AM	??	0:16.07	wal writer process (postmaster)
postgres	831	825	0	Tue12AM	??	0:11.34	autovacuum launcher process (postmaster)
postgres	832	825	0	Tue12AM	??	0:07.63	stats collector process (postmaster)
postgres	13003	825	0	3:44PM	??	0:00.01	postgres test [local] idle (postmaster)
postgres	13002	12997	0	3:44PM	ttyq1	0:00.03	/u/pgsql/bin/psql test

top

```
$ top -c
```

```
top - 10:29:47 up 23 days, 18:53, 6 users, load average: 1.73, 1.49, 0.81
```

```
Tasks: 387 total, 2 running, 385 sleeping, 0 stopped, 0 zombie
```

```
%Cpu(s): 5.9 us, 0.5 sy, 0.0 ni, 93.7 id, 0.0 wa, 0.0 hi, 0.0 si, 0.0 st
```

```
KiB Mem: 24734444 total, 19187724 used, 5546720 free, 532280 buffers
```

```
KiB Swap: 6369276 total, 168292 used, 6200984 free. 16936936 cached Mem
```

PID	USER	PR	NI	VIRT	RES	SHR	S	%CPU	%MEM	TIME+	COMMAND
32037	postgres	20	0	190980	27940	21420	R	100.0	0.1	0:09.74	postgres: postgres test [local] INSERT
32061	root	20	0	26056	3240	2444	R	0.7	0.0	0:00.09	top -c

Query Monitoring

```
test=> SELECT * FROM pg_stat_activity;
```

```
...
datid          | 16384
datname        | test
pid           | 16382
usesysid       | 10
username       | postgres
application_name | psql
client_addr    |
client_hostname |
client_port    | -1
backend_start  | 2018-04-15 09:00:26.467813-04
xact_start     | 2018-04-15 09:00:48.028667-04
query_start    | 2018-04-15 09:00:48.028667-04
state_change   | 2018-04-15 09:00:48.028671-04
wait_event_type |
wait_event     |
state          | active
backend_xid    |
backend_xmin   | 556
query          | SELECT * FROM pg_stat_activity;
backend_type    | client backend
```

Access Statistics

pg_stat_all_indexes	view	postgres
pg_stat_all_tables	view	postgres
pg_stat_database	view	postgres
pg_stat_sys_indexes	view	postgres
pg_stat_sys_tables	view	postgres
pg_stat_user_indexes	view	postgres
pg_stat_user_tables	view	postgres
pg_statio_all_indexes	view	postgres
pg_statio_all_sequences	view	postgres
pg_statio_all_tables	view	postgres
pg_statio_sys_indexes	view	postgres
pg_statio_sys_sequences	view	postgres
pg_statio_sys_tables	view	postgres
pg_statio_user_indexes	view	postgres
pg_statio_user_sequences	view	postgres
pg_statio_user_tables	view	postgres

Database Statistics

```
test=> SELECT * FROM pg_stat_database;
```

```
...
```

```
-[ RECORD 4 ]-+-----
```

datid		16384
datname		test
numbackends		1
xact_commit		188
xact_rollback		0
blks_read		95
blks_hit		11832
tup_returned		64389
tup_fetched		2938
tup_inserted		0
tup_updated		0
tup_deleted		0

Table Activity

```
test=> SELECT * FROM pg_stat_all_tables;
```

```
-[ RECORD 10 ]-----+-----
```

relid	2616
schemaname	pg_catalog
relname	pg_opclass
seq_scan	2
seq_tup_read	2
idx_scan	99
idx_tup_fetch	99
n_tup_ins	0
n_tup_upd	0
n_tup_del	0
n_tup_hot_upd	0
n_live_tup	0
n_dead_tup	0
last_vacuum	
last_autovacuum	
last_analyze	
last_autoanalyze	

Table Block Activity

```
test=> SELECT * FROM pg_statio_all_tables;
```

```
-[ RECORD 50 ]--+-
```

relid	2602
schemaname	pg_catalog
relname	pg_amop
heap_blks_read	3
heap_blks_hit	114
idx_blks_read	5
idx_blks_hit	303
toast_blks_read	
toast_blks_hit	
tidx_blks_read	
tidx_blks_hit	

Analyzing Activity

- Heavily used tables
- Unnecessary indexes
- Additional indexes
- Index usage
- TOAST usage

CPU

\$ vmstat 5

procs			memory		page						disks		faults			cpu		
r	b	w	avm	fre	flt	re	pi	po	fr	sr	s0	s0	in	sy	cs	us	sy	id
1	0	0	501820	48520	1234	86	2	0	0	3	5	0	263	2881	599	10	4	86
3	0	0	512796	46812	1422	201	12	0	0	0	3	0	259	6483	827	4	7	88
3	0	0	542260	44356	788	137	6	0	0	0	8	0	286	5698	741	2	5	94
4	0	0	539708	41868	576	65	13	0	0	0	4	0	273	5721	819	16	4	80
4	0	0	547200	32964	454	0	0	0	0	0	5	0	253	5736	948	50	4	46
4	0	0	556140	23884	461	0	0	0	0	0	2	0	249	5917	959	52	3	44
1	0	0	535136	46280	1056	141	25	0	0	0	2	0	261	6417	890	24	6	70

I/O

```
$ iostat 5
```

tty		sd0			sd1			sd2			% cpu				
tin	tout	sps	tps	msps	sps	tps	msps	sps	tps	msps	usr	nic	sys	int	idl
7	119	244	11	6.1	0	0	27.3	0	0	18.1	9	1	4	0	86
0	86	20	1	1.4	0	0	0.0	0	0	0.0	2	0	2	0	96
0	82	61	4	3.6	0	0	0.0	0	0	0.0	2	0	2	0	97
0	65	6	0	0.0	0	0	0.0	0	0	0.0	1	0	2	0	97
12	90	31	2	5.4	0	0	0.0	0	0	0.0	4	0	3	0	93
24	173	6	0	4.9	0	0	0.0	0	0	0.0	48	0	3	0	49
0	91	3594	63	4.6	0	0	0.0	0	0	0.0	11	0	4	0	85

Disk Usage

```
test=> \df *size*
```

List of functions				
Schema	Name	Result data type	Argument data types	Type
pg_catalog	pg_column_size	integer	"any"	normal
pg_catalog	pg_database_size	bigint	name	normal
pg_catalog	pg_database_size	bigint	oid	normal
pg_catalog	pg_indexes_size	bigint	regclass	normal
pg_catalog	pg_relation_size	bigint	regclass	normal
pg_catalog	pg_relation_size	bigint	regclass, text	normal
pg_catalog	pg_size_pretty	text	bigint	normal
pg_catalog	pg_table_size	bigint	regclass	normal
pg_catalog	pg_tablespace_size	bigint	name	normal
pg_catalog	pg_tablespace_size	bigint	oid	normal
pg_catalog	pg_total_relation_size	bigint	regclass	normal

Database File Mapping - oid2name

```
$ oid2name
```

```
All databases:
```

```
-----  
18720  = test1  
1      = template1  
18719  = template0  
18721  = test  
18735  = postgres  
18736  = cssi
```

Table File Mapping

```
$ cd /usr/local/pgsql/data/base
```

```
$ oid2name
```

```
All databases:
```

```
-----  
16817  = test2  
16578  = x  
16756  = test  
1      = template1  
16569  = template0  
16818  = test3  
16811  = floattest
```

```
$ cd 16756
```

```
$ ls 1873*
```

```
18730  18731  18732  18735  18736  18737  18738  18739
```

Table File Mapping

```
$ oid2name -d test -o 18737
```

```
Tablename of oid 18737 from database "test":
```

```
-----  
18737  = ips
```

```
$ oid2name -d test -t ips
```

```
Oid of table ips from database "test":
```

```
-----  
18737  = ips
```

```
$ # show disk usage per database
```

```
$ cd /usr/local/pgsql/data/base
```

```
$ du -s * |
```

```
> while read SIZE OID
```

```
> do
```

```
>     echo "$SIZE      `oid2name -q | grep ^$OID' "`
```

```
> done |
```

```
> sort -rn
```

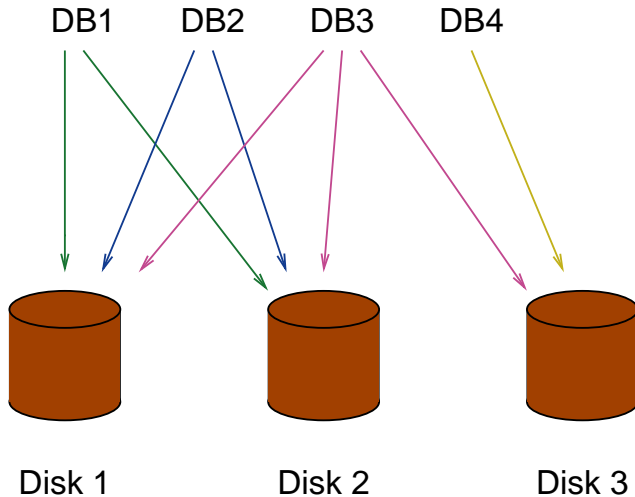
```
2256      18721  = test
```

```
2135      18735  = postgres
```

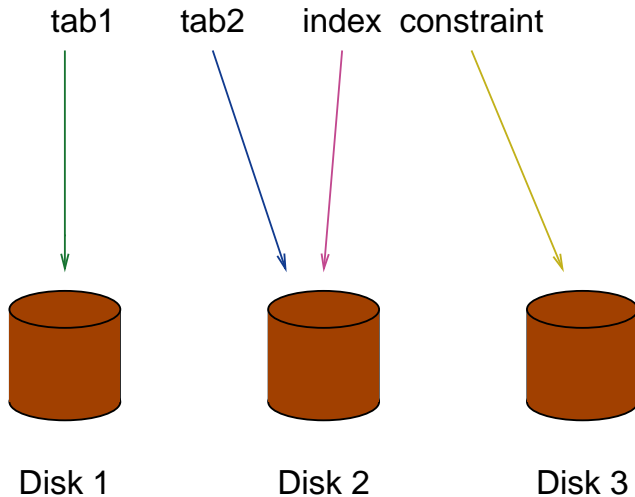
Disk Balancing

- Move pg_wal to another drive using symlinks
- Tablespaces

Per-Database Tablespaces



Per-Object Tablespaces



Analyzing Locking

```
$ ps -f -Upostgres
```

PID	TT	STAT	TIME	COMMAND
9874	??	I	0:00.07	postgres test [local] idle in transaction (postmaster)
9835	??	S	0:00.05	postgres test [local] UPDATE waiting (postmaster)
10295	??	S	0:00.05	postgres test [local] DELETE waiting (postmaster)

```
test=> SELECT * FROM pg_locks;
```

relation	database	transaction	pid	mode	granted
17143	17142		9173	AccessShareLock	t
17143	17142		9173	RowExclusiveLock	t
		472	9380	ExclusiveLock	t
		468	9338	ShareLock	f
		470	9338	ExclusiveLock	t
16759	17142		9380	AccessShareLock	t
17143	17142		9338	AccessShareLock	t
17143	17142		9338	RowExclusiveLock	t
		468	9173	ExclusiveLock	t

Miscellaneous Tasks

- Log file rotation, syslog
- Upgrading
 - pg_dump, restore
 - pg_upgrade
 - Slony
- Migration

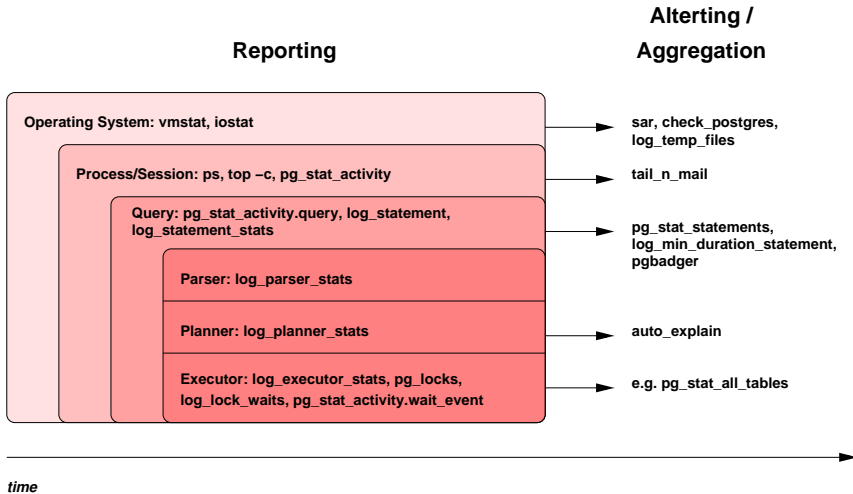
Administration Tools

- pgadmin
- phppgadmin

External Monitoring Tools

- Alerting: `check_postgres`, `tail_n_mail`, Nagios
- Server analysis: Munin, Cacti, Zabbix, Nagios, MRTG, Prometheus, Grafana
- Queries: `pg_stat_statements`, `auto_explain`, pgbadger
- Commercial: Postgres Enterprise Manager (PEM), Circonus, VividCortex

Monitoring Summary



5. Recovery



<https://www.flickr.com/photos/coastguardnews/>

Client Application Crash

Nothing Required. Transactions in progress are rolled back.

Graceful Postgres Server Shutdown

Nothing Required. Transactions in progress are rolled back.

Abrupt Postgres Server Crash

Nothing Required. Transactions in progress are rolled back.

Operating System Crash

Nothing Required. Transactions in progress are rolled back. Partial page writes are repaired.

Disk Failure

Restore from previous backup or use PITR.

Accidental DELETE

Recover table from previous backup, perhaps using `pg_restore`. It is possible to modify the backend code to make deleted tuples visible, dump out the deleted table and restore the original code. All tuples in the table since the previous vacuum will be visible. It is possible to restrict that so only tuples deleted by a specific transaction are visible.

Write-Ahead Log (WAL) Corruption

See `pg_resetwal`. Review recent transactions and identify any damage, including partially committed transactions.

File Deletion

It may be necessary to create an empty file with the deleted file name so the object can be deleted, and then the object restored from backup.

Accidental DROP TABLE

Restore from previous backup.

Accidental DROP INDEX

Recreate index.

Accidental DROP DATABASE

Restore from previous backup.

Non-Starting Installation

Restart problems are usually caused by write-ahead log problems. See `pg_resetwal`. Review recent transactions and identify any damage, including partially committed transactions.

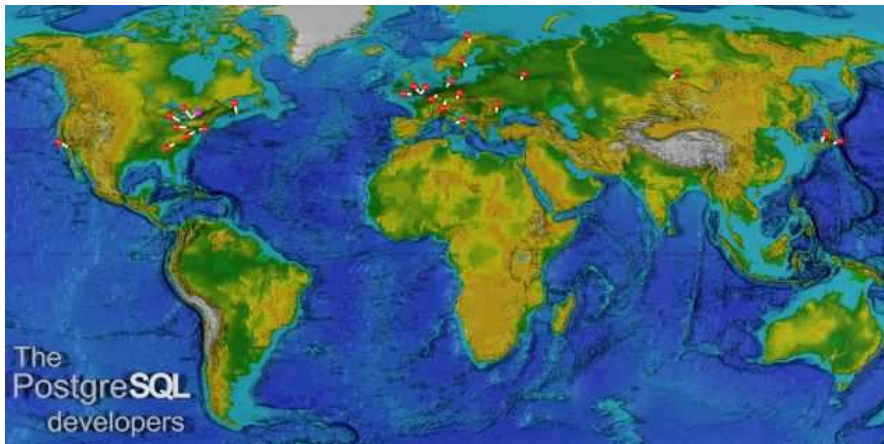
Index Corruption

Use REINDEX.

Table Corruption

Try reindexing the table. Try identifying the corrupt OID of the row and transfer the valid rows into another table using `SELECT...INTO...WHERE oid != ###`. Use *pageinspect* to analyze the internal structure of the table.

Conclusion



<https://momjian.us/presentations>