Decoding postgresql.conf

Which parameters to tweak, and when.

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The journey of a transaction

Seven gates where we'll meet the parameters

1	2	3	4	5	6	7
Knocks on the door	Asks for scratch	Hires helpers	Writes the diary	Tells the replica	Leaves dead rows	Put on glasses
Connection Management	**Memory**	**Parallelism**	**WAL & Checkpoints**	**Replication**	**Autovacuum**	**Logging**

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The defaults are good. Until they aren't.

Postgres ships with ~350 GUCs. Do you really need to tune all?

01

Don't tune in the dark

Most parameters have a log signature, system view info or metrics for monitoring. Investigate those first.

02

Parameters interact

max_parallel_workers ≤ max_worker_processes. work_mem × connections × hash operations. Slots vs WAL retention.

03

Wait for evidence

If the log isn't complaining, performance is good/acceptable, the views/metrics looks healthy — leave it alone.

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STAGE 1 · THE DOORMEN

Connection Management

In this section

`max_connections`
`idle_session_timeout`
`transaction_timeout`
`idle_in_transaction_session_timeout`
`statement_timeout`

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max_connections is not a target. It's a ceiling.

- Each backend ≈ a process. Each process ≈ memory + file descriptors.
- Raising max_connections does not give you more throughput. It gives you more processes competing for the same CPU and lock manager.
- **Real answer is almost always a pooler (Supavisor, PgBouncer etc).**

WATCH IN LOGS

```
FATAL: sorry, too many clients already
FATAL: remaining connection slots are
  reserved for non-replication...
```

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```
pg_stat_activity

pg_stat_database (dataname, numbackends)
```

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The four timeouts: what they kill, and when

statement_timeout

Caps a single statement.

default: 0 (off)

transaction_timeout (PG 17+)

Caps an entire transaction — including idle time between statements.

default: 0 (off)

idle_in_transaction_session_timeout

Kills a transaction which is open while doing nothing. Antidote to bloat from BEGIN-then-forget.

default: 0 (off)

idle_session_timeout

Kills a connection with no open transaction. Pair with pooler timeouts

default: 0 (off)

WATCH IN LOGS

```
FATAL: terminating connection
  due to idle-in-transaction
  timeout

ERROR: canceling statement
  due to statement timeout

FATAL:  terminating connection due to
transaction timeout
```

MONITOR VIA

```
pg_stat_activity
  WHERE state =
  'idle in transaction'
```

The statement_timeout is ignored when transaction_timeout is active and shorter

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STAGE 2 · SCRATCH SPACE

Resource Usage · Memory

In this section

`shared_buffers`
`work_mem`
`logical_decoding_work_mem`
`maintenance_work_mem`
`autovacuum_work_mem`

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shared_buffers — the page cache Postgres actually owns

- Postgres reads through its own buffer cache before touching OS page cache.
- Rule of thumb: 25% of RAM on a dedicated server; OS cache also helps.
- Change requires restart
- *Wrong question: "Is shared_buffers big enough?"*
  Right question: "What does my cache hit ratio look like?"

```
SELECT relname, heap_blks_read, heap_blks_hit,
       round(100.0*heap_blks_hit/
nullif(heap_blks_hit+heap_blks_read,0),2) AS hit_pct
FROM pg_statio_user_tables ORDER BY heap_blks_read DESC LIMIT
10;
```

WATCH IN LOGS

```
LOG: checkpoint complete:
  buffers_written=...

auto_explain.log_buffers (if its enabled will
log plan with buffer information)
```

MONITOR VIA

```
pg_stat_database
  blks_hit, blks_read

pg_statio_user_tables

pg_buffercache  (extension)
```

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work_mem — the most-multiplied number in your conf

`work_mem × N × M`

N = concurrent backends · M = sort/hash nodes per plan

4 MB default × 200 conns × 3 hashes/plan ≈ 2.4 GB on the floor.

- Set per-session for analytics: SET work_mem = '256MB';
- Set per role: ALTER ROLE etl SET work_mem = '512MB';
- hash_mem_multiplier (PG 13+) lets hash ops take more without raising the global ceiling.

WATCH IN LOGS

```
LOG: temporary file: path
  "base/pgsql_tmp/...",
  size 134217728
STATEMENT: SELECT ...

(External merge Disk:
 ... in EXPLAIN ANALYZE)
```

MONITOR VIA

```
log_temp_files = 0

pg_stat_database
  temp_files, temp_bytes

EXPLAIN (ANALYZE, BUFFERS)
  → 'Sort Method:'
```

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maintenance_work_mem + autovacuum_work_mem

maintenance_work_mem

Used by VACUUM, CREATE INDEX, REINDEX, ALTER TABLE ADD FK.

`default: 64MB`

autovacuum_work_mem

Per autovacuum worker. If -1 (default), falls back to maintenance_work_mem

`default: -1 (→ maintenance_work_mem)`

THE INTERACTION

maintenance_work_mem = 2GB + autovacuum_max_workers = 6 + autovacuum_work_mem = -1 → up to 12 GB of autovacuum RAM alone.

Set autovacuum_work_mem to a sane per-worker value (e.g. 512MB), keep maintenance_work_mem big for index builds.

WATCH IN LOGS

```
LOG: automatic vacuum of table "..." : index scans: 3   ←
multiple passes = m_w_m too small
```

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`pg_stat_progress_vacuum (phase = 'vacuuming index'), also check max_dead_tuple_bytes`

Till v16 : For the collection of dead tuple identifiers, autovacuum is only able to utilize up to a maximum of `1GB` of memory, so setting `autovacuum_work_mem` to a value higher than that has no effect

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logical_decoding_work_mem

- Per walsender doing logical decoding. Buffers transaction changes in memory before spilling to disk.
- Default 64 MB. Too small for long-running transactions or bulk loads → spill files on the publisher.
- Symptoms: 'reorderbuffer' spill files in pg_replslot/<slot>/; replication lag despite fast network.
- Streaming logical replication (PG 14+) eases this — but only if the subscriber supports it.

WATCH IN

```
(spill to disk — look at)
$PGDATA/pg_replslot/
  <slot_name>/xid-*.spill
```

MONITOR VIA

```
pg_stat_replication_slots
  spill_txns, spill_count,
  spill_bytes, stream_txns
pg_replication_slots
  confirmed_flush_lsn
```

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STAGE 3 · THE CREW

Background Workers & Parallelism

In this section

`max_worker_processes`
`max_parallel_workers`
`max_parallel_workers_per_gather` `max_parallel_maintenance_workers`

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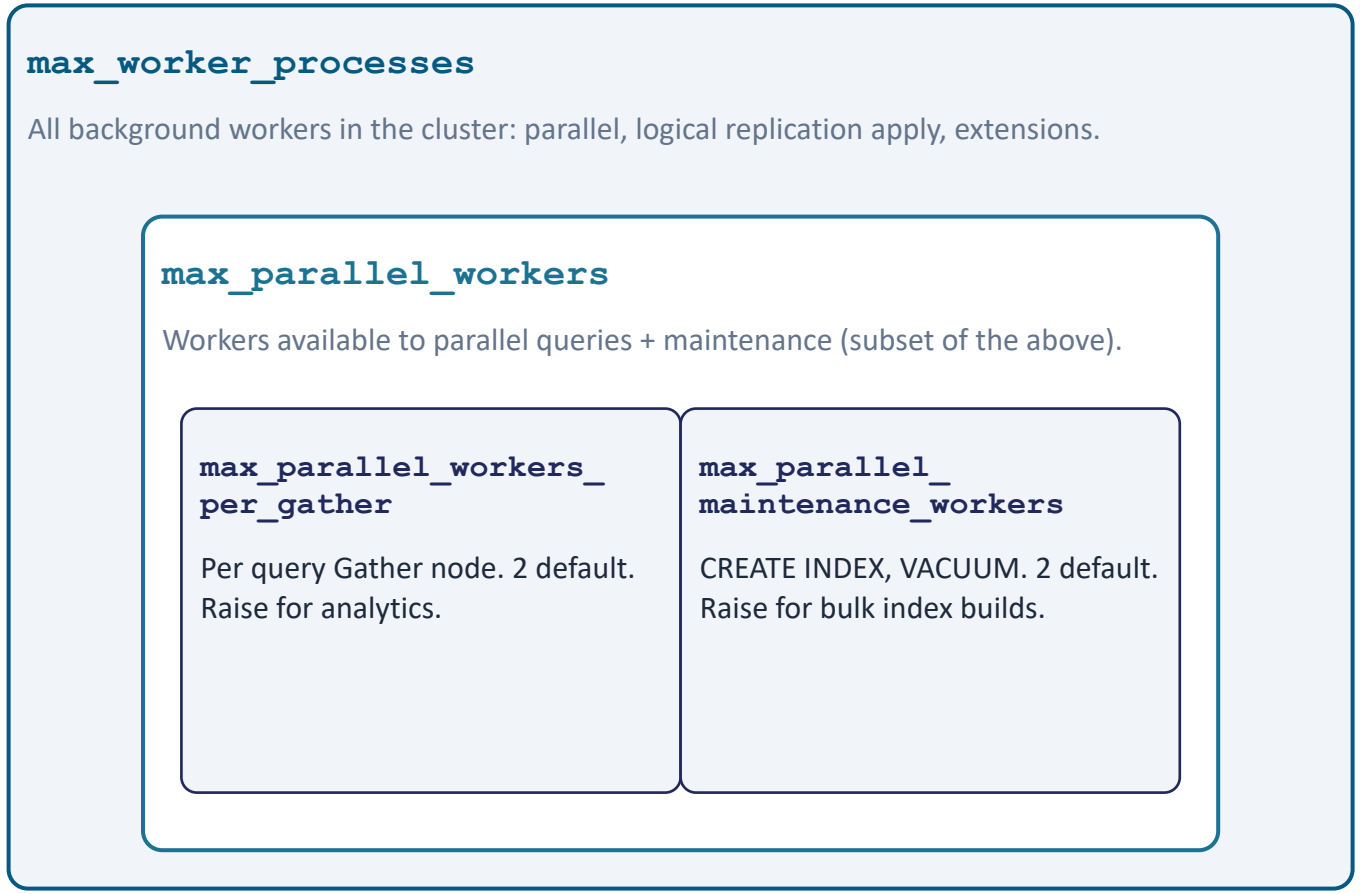
Three concentric limits — get the order right



Order matters

Raising the inner two without raising max_parallel_workers does nothing — queries silently degrade to fewer workers than planned.

And neither limit matters if max_worker_processes is too low — that's the ceiling that also feeds logical replication apply workers.

WATCH IN LOGS

```
LOG: planned vs launched
  workers: 4 / 2  (in
  EXPLAIN ANALYZE)
```

MONITOR VIA

```
pg_stat_activity
  backend_type =
  'parallel worker'
```

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STAGE 4 · THE DIARY

WAL · Checkpoints · Archiving

In this section

`checkpoint_timeout` `max_wal_size`
`archive_mode` `archive_command`

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Two ways to trigger a checkpoint — pick the polite one

TIMED

checkpoint_timeout

Default 5 min → raise to 15–30 min for write-heavy (full page writes reduction)
Smooths I/O, but increases recovery time.

VOLUME

max_wal_size

Default 1GB → raise so timeout fires first.
If volume forces checkpoints, investigate the I/O load

The principle: checkpoints should be timed, not forced.

WATCH IN LOGS

```
LOG: checkpoints are occurring too frequently (12 seconds
  apart)
HINT: Consider increasing max_wal_size.
```

MONITOR VIA

```
pg_stat_checkpointer   (PG 17+)
pg_stat_bgwriter       (pre-17)
  checkpoints_timed  vs checkpoints_req
  → ratio >> 90% timed = healthy
```

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archive_mode + archive_command — your PITR depends on this

- archive_mode = on → archiver process starts. Restart required to change.
- archive_command → shell command run for each WAL segment. Must return 0 only on success and on a verified durable copy.
- If the command never succeeds, WAL accumulates in pg_wal/ → disk fills → the cluster stops.
- **Use pgBackRest / WAL-G / Barman instead of hand-rolling cp/rsync.**

```
# Bad — returns 0 even if cp failed silently:
archive_command = 'cp %p /mnt/archive/%f'

# Better — test for prior existence, fsync, then move:
archive_command = 'pgbackrest --stanza=main archive-push %p'
```

WATCH IN LOGS

```
LOG: archive command
  failed with exit code 1
LOG: archiver process
  (PID ...) exited
WARNING: archiving write-
  ahead log file "..."
  failed too many times
```

MONITOR VIA

```
pg_stat_archiver
  archived_count,
  failed_count,
  last_archived_time,
  last_failed_time
```

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STAGE 5 · TELLING THE REPLICA

Replication

In this section

`max_wal_senders` `max_replication_slots`
`wal_keep_size` `max_slot_wal_keep_size`
`idle_replication_slot_timeout`
`max_standby_archive_delay` `max_standby_streaming_delay`
`hot_standby_feedback`

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Senders, slots, and the idle-slot timer

max_wal_senders

How many concurrent walsender processes. Each streaming replica, logical subscriber, or pg_basebackup uses one.

default: 10

max_replication_slots

How many slots can exist. Slots are the persistent bookmark a consumer leaves on the WAL.

default: 10

idle_replication_slot_timeout (PG 18+)

Auto-invalidates a slot whose consumer has been gone too long.

default: 0 (off)

Slots are persistent. Replicas may not be.

A dropped replica with a still-defined slot keeps holding WAL — until your disk says no. idle_replication_slot_timeout finally lets you bound that.

WATCH IN LOGS

```
ERROR: requested WAL segment 000...  has already been removed
```

MONITOR VIA

`pg_replication_slots` · `pg_stat_replication`

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wal_keep_size vs max_slot_wal_keep_size

`wal_keep_size`

Minimum WAL to retain for non-slot replicas

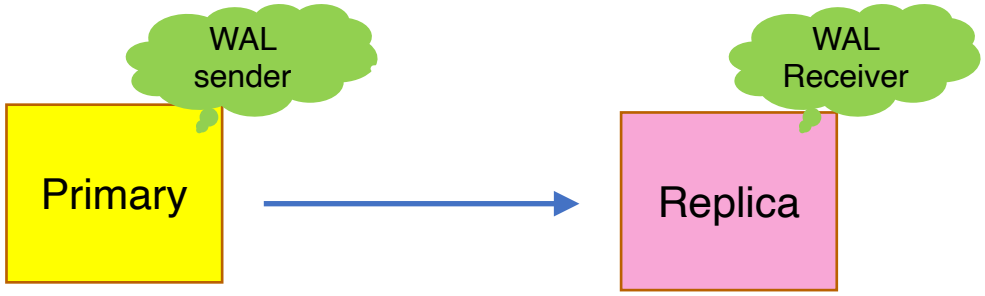
- Unconditional retention. WAL stays even if no one's reading it.
- Used when replicas don't have slots (rare in modern setups).
- Default 0 — slots are the modern path.

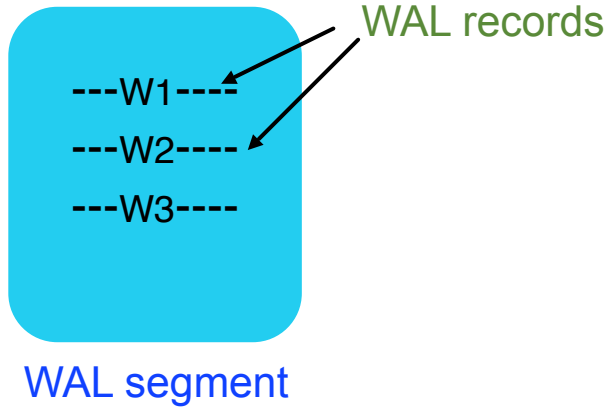
`max_slot_wal_keep_size`

Maximum WAL a slot is allowed to keep before being invalidated

- The safety valve. Above this, slot becomes invalidated and replica must re-sync.
- **Better to lose a replica than the primary.**
- Set to a fraction of free disk on pg_wal partition.

Understanding replication conflicts





Time	Primary	Primary WAL	Replica	Replica WAL
t0	-	Sending WAL record W1	Reading from “A”	Received WAL record W1
t1	WAL generating operation on ”A”	Sending WAL record W2	Reading from “A”	Received W1 and W2, waiting to apply
t2	WAL generating operation completed	Sending WAL record W3	Still Reading from “A”	Still waiting to apply W1 and W2
t4	-	Sending WAL record W4	Cancelling statement due to conflict with recovery	Cancel query (based on conditions and after a threshold), and apply WAL

RECOVERY_CONFLICT_SNAPSHOT

Time	Primary	Replica
t0	-	Reading from “A”
t1	Update/Delete on ”A”	Still Reading from “A”
t2	Vacuum triggered	Still Reading from “A”
t4	-	Cancelling statement due to conflict with recovery, as the rows need to be removed

Understanding replication conflicts

Long-running query on the replica vs WAL replay - Lag vs query cancellation - trade-off to make

`max_standby_streaming_delay`

How long replay will wait for queries to finish before canceling them, when WAL arrives via streaming. -1 = wait forever (lag grows).

`default: 30s`

`max_standby_archive_delay`

Same idea, but for WAL applied from the archive

`default: 30s`

`hot_standby_feedback`

Tells the primary the replica's oldest xmin so vacuum on the primary won't remove rows the replica still needs. Drawback = primary bloat

`default: off`

WATCH IN LOGS

```
ERROR: canceling statement due to conflict with recovery
(note the error detail carefully to find the fix)
```

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`pg_stat_database_conflicts`

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Code Blame Raw

```
2553  errdetail_recovery_conflict(RecoveryConflictReason reason)
2554  {
2555      switch (reason)
2556      {
2557          case RECOVERY_CONFLICT_BUFFERPIN:
2558              errdetail("User was holding shared buffer pin for too long.");
2559              break;
2560          case RECOVERY_CONFLICT_LOCK:
2561              errdetail("User was holding a relation lock for too long.");
2562              break;
2563          case RECOVERY_CONFLICT_TABLESPACE:
2564              errdetail("User was or might have been using tablespace that must be dropped.");
2565              break;
2566          case RECOVERY_CONFLICT_SNAPSHOT:
2567              errdetail("User query might have needed to see row versions that must be removed.");
2568              break;
2569          case RECOVERY_CONFLICT_LOGICALSLOT:
2570              errdetail("User was using a logical replication slot that must be invalidated.");
2571              break;
2572          case RECOVERY_CONFLICT_STARTUP_DEADLOCK:
2573              errdetail("User transaction caused deadlock with recovery.");
2574              break;
2575          case RECOVERY_CONFLICT_BUFFERPIN_DEADLOCK:
2576              errdetail("User transaction caused buffer deadlock with recovery.");
2577              break;
2578          case RECOVERY_CONFLICT_DATABASE:
2579              errdetail("User was connected to a database that must be dropped.");
2580              break;
2581      }
```

hot_standby_feedback

https://github.com/postgres/postgres/blob/master/src/backend/tcop/postgres.c

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STAGE 6 · CLEANING CREW

Autovacuum

In this section

`autovacuum` `autovacuum_freeze_max_age` `_worker_slots` `_max_workers` `_max_parallel_workers` `_vacuum_threshold` `_scale_factor` `_vacuum_max_threshold` `_analyze_threshold` `_analyze_scale_factor`

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The formula — when does autovacuum fire?

```
trigger = LEAST(
    autovacuum_vacuum_threshold + autovacuum_vacuum_scale_factor × reltuples,
    autovacuum_vacuum_max_threshold      -- PG 18+: hard cap on the trigger
)
```

_vacuum_threshold
Baseline dead tuples before considering. Tiny tables benefit from a small value.

default: 50

_vacuum_scale_factor
Fraction of reltuples added on top. 0.2 = 20% of table.

default: 0.2

_vacuum_max_threshold
PG 18+. Caps the trigger absolutely. Huge tables no longer wait until 20% to clean.

default: 100,000,000

_analyze_threshold / _scale_factor
Same math, for ANALYZE. Stats freshness matters as much as bloat.

default: 50 / 0.1

For busy tables, per-table override are a good direction:

```
ALTER TABLE orders SET (autovacuum_vacuum_scale_factor = 0.05,
                        autovacuum_vacuum_threshold = 1000);
```

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autovacuum_freeze_max_age — the clock you can't ignore

- Postgres XIDs are 32 bits. They wrap. To keep history visible, old tuples must be "frozen".
- When a table's oldest XID is older than autovacuum_freeze_max_age, an anti-wraparound vacuum kicks in
- **If they fall behind, the cluster will eventually refuse new XIDs and shut down to protect itself.**

WATCH IN LOGS

```
WARNING: database "db"
  must be vacuumed within
  N transactions

HINT: To avoid a database
  shutdown, execute a
  database-wide VACUUM

ERROR: database is not
  accepting commands to
  avoid wraparound...
```

MONITOR VIA

```
SELECT datname,
  age(datfrozenxid)
FROM pg_database
ORDER BY 2 DESC;
```

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Slots, workers, and the parallel sub-crew

autovacuum_worker_slots (PG 18+)

How many worker slots are reserved at startup. The pool the launcher draws from. Decouples capacity planning from runtime concurrency.

default: 16

autovacuum_max_workers

How many slots may be active at once. Pre-PG18 this was both the pool and the limit. Now: tune for concurrency.

default: 3

autovacuum_max_parallel_workers (PG 18+)

Across all autovacuum workers, how many parallel workers may help index cleanup. Bounded by max_parallel_workers.

default: 0

THE NEW MODEL (PG 18+)

Reserve plenty of slots (worker_slots), keep runtime concurrency modest (max_workers), and turn on parallel index cleanup on huge tables. Workers borrow from max_parallel_workers — see Stage 3, the limits compose.

What to watch — autovacuum at a glance

WATCH IN LOGS

```
LOG: automatic vacuum of
  table "x":
  index scans: 3
  pages: 0 removed, ...
  tuples: N removed,
    M remain, K dead but
    not yet removable

  ← dead but not removable
    = a held xmin somewhere
      (replica? slot? long
      transaction?)

WARNING: database "db"
  must be vacuumed within
  N transactions
```

MONITOR VIA

```
pg_stat_user_tables
  n_dead_tup, n_live_tup,
  last_autovacuum,
  last_autoanalyze

pg_stat_progress_vacuum
  phase, heap_blks_scanned,
  num_dead_tuples

pg_stat_progress_analyze

log_autovacuum_min_duration = 0
  → every autovacuum run
    leaves a logged summary
```

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STAGE 7 · PUT ON GLASSES

Reporting & Logging

In this section

`log_min_duration_statement`
`log_autovacuum_min_duration`
`log_statement`
`log_temp_files`

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The four parameters that make the rest of this talk visible

log_min_duration_statement

Log any statement that ran longer than N. -1 = off, 0 = log everything. Most people start at 1000 (ms) and walk it down.

default: -1

log_autovacuum_min_duration

Log any autovacuum that ran longer than N. 0 = log every run (recommended on busy systems).

default: 10min

log_statement

Categorical: 'none' | 'ddl' | 'mod' | 'all'. DDL on a production system is almost always cheap to log and invaluable for forensics.

default: none

log_temp_files

Log temp file creation over N bytes. 0 = log all. Companion to work_mem tuning.

default: -1

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Combine with pg_stat_statements for query-shape totals, not just slow individuals.

CHEAT SHEET

Error / log line	Look at parameter(s)	Open this view
`FATAL: sorry, too many clients already`	max_connections (and use a pooler)	pg_stat_activity
`canceling statement due to statement timeout`	statement_timeout / transaction_timeout	pg_stat_activity, pg_stat_statements
`temporary file ... size NNN`	work_mem, hash_mem_multiplier	pg_stat_database (temp_*)
`checkpoints are occurring too frequently`	max_wal_size, checkpoint_timeout	pg_stat_checkpointer / pg_stat_bgwriter
`requested WAL segment ... has already been removed`	max_slot_wal_keep_size, wal_keep_size	pg_replication_slots, pg_stat_replication
`canceling statement due to conflict with recovery`	max_standby_streaming_delay, hot_standby_feedback	pg_stat_database_conflicts
`must be vacuumed within N transactions`	autovacuum_freeze_max_age, autovacuum_max_workers	pg_database (age(datfrozenxid)), pg_stat_progress_vacuum

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Key Takeaways

- **UPGRADE** !!! to the latest major version
- **idle_in_transaction_session_timeout** - to timeout sessions which can hold xid horizon
- Setup effective **monitoring** and **logging** for your database
- Maximum used transaction IDs should be monitored in **every** PostgreSQL database
- Do not tune in the dark

Thank you.

Questions, war stories, corrections — all welcome.

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Feedback : https://2026.pgday.ch/feedback/?proposal_id=435

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