Qubit Drift Summary

This document summarizes how and why qubits drift on real superconducting quantum hardware (e.g., IBM devices like *ibm_torino*), and over what timeframes different sources of drift typically occur.

Overview

Superconducting qubits are not static components. Their physical properties change over time due to:

- temperature fluctuations in the dilution refrigerator
- material defects and microscopic two-level systems (TLS)
- electromagnetic interference
- vibrations and drift in control electronics

These changes alter how qubits respond to microwave pulses, how reliably they maintain state, and how accurately they can be measured. Drift requires frequent recalibration.

Drift Timescales (Practical Values)

Different parameters drift at different rates:

1. Readout Bias Drift

Timeframe: **10–60 minutes**, occasionally a few hours.

The readout resonators used to distinguish $|0\rangle$ from $|1\rangle$ slowly drift due to thermal and electronic noise. This affects the probability of misidentifying measurement results. Your confusion matrix corrects for this.

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2. Qubit Frequency Drift

Timeframe: **1–6 hours**.

Transmon qubits have resonance frequencies in the ~5–7 GHz range. These frequencies drift by a few kHz to tens of kHz per hour. Even small drifts affect the fidelity of microwave control pulses and gate operations.

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3. Gate Pulse Calibration Drift (Amplitude/Phase)

Timeframe: **2–6 hours**.

Single-qubit gates (SX, RZ) and especially two-qubit gates (cross-resonance CX) require highly calibrated pulse shapes. Their calibrations degrade with time as the environment slowly shifts.

Quantum cloud providers recalibrate these multiple times daily.

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4. Crosstalk Drift (Qubit–Qubit Interactions)

Timeframe: **hours**.

Coupled qubit systems change their cross-resonance response due to tiny vibrations, temperature drifts, or local heating. This affects two-qubit gate performance.

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5. Full-System Calibration Cycles

Timeframe: **6–24 hours**.

Large devices undergo major recalibration cycles at least once every day—often overnight—where pulse amplitudes, frequencies, and readout parameters are adjusted together.

What This Means for Experiments

Your confusion matrix remains valid for roughly 30–90 minutes.

This is the stability window for readout error mitigation. Past that, the readout drift tends to invalidate the calibration.

Gate fidelities and qubit frequencies drift over a few hours.

Serious experiments often:

- run large batches of circuits right after calibration,
- log calibration timestamps,
- recalibrate before every major batch of workloads.

Drift is expected and normal.

Near-term quantum computers are analog devices subject to environmental and electronic noise. Drift is not a flaw—it is intrinsic to current technology.

Summary Table

Parameter	Drift Timescale	Notes
Readout bias	10–60 minutes	Calibration required for accurate measurement.
Qubit frequency	1–6 hours	Affects precise pulse tuning.
Gate pulse calibration	2–6 hours	Critical for high-fidelity gates.
Crosstalk behavior	Hours	Influences CX performance.
Full system recalibration	6–24 hours	Typically done overnight.

Superconducting qubits work well enough to run complex experiments, but only within the stability windows described above. Understanding drift helps you know when your mitigation is valid and when recalibration is needed.