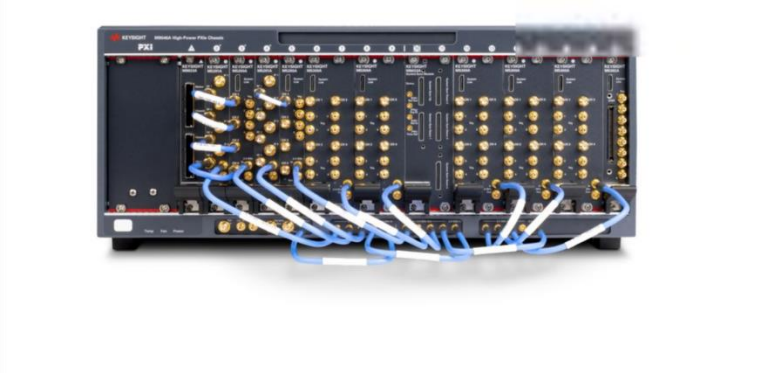
System Calibration, User Calibration and Temperature Management

2025B QCS

This document outlines how calibration and temperature are managed in the QCS system, including when calibration is required, how temperature affects system performance, and what is in place to ensure reliable operation.



KEYSIGHT

Reset Calibration and Calibration Validity

What is Reset Calibration?

Reset Calibration is a system-level procedure required when initializing a system for the first time, or after hardware changes, such as module or chassis replacement. It establishes a reference temperature used to validate the system's internal timing and synchronization across all chassis and instruments. Running a Reset Calibration can cause small (< 100 ps) changes in the output pulse waveforms that change the relative phase between channels, so repeating any qubit calibration is recommended.

Calibration Validity Range

Once Reset Calibration is performed, the calibration data remains valid across successive initializations, power cycles, and cold starts, provided the system operates within a defined temperature range around the reference temperature. This range, currently set to ±10 ºC, is based on Keysight's internal characterization.

The system automatically checks temperature during successive system initialization and ensures it remains within this range.

If any instrument temperature is outside the valid range during initialization, the process will not complete, and the user will be notified. This may be due to environmental changes (e.g., HVAC issues) or an initial calibration performed too soon after initial turn on. In such cases, users can:

- Retry initialization once the room temperature stabilizes.
- Temporarily disable the temperature check during alignment (see section "How to disable the initialization temperature check").
- If hardware has been replaced or added (e.g., chassis, instruments, clock or sync cables), a new Reset Calibration is required (see section "How to force a Reset Calibration").
- If the original Reset Calibration was performed under unstable environmental conditions, a new Reset Calibration should be performed to establish a reliable reference temperature.

How to force a Reset Calibration?

To force a Reset Calibration, remove the file:

```
<Drive>:\ProgramData\Keysight\Qcs\Ism\TseCalibrationComplete
```

If this is a multi-host system, this will be located on the ISM leader.
Once the file has been removed, restart the QCS control software using:

```
qcsconfigurecli.exe service restart ism ism
```

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Important: Forcing a Reset Calibration will invalidate all existing user calibration data. Ensure this action is necessary before proceeding by making sure it is not caused by a transient environmental / HVAC issue.

How to disable the temperature checks during alignment

For single chassis systems where the Configuration Tool has never been used:

Open the following file:

<Drive>:\ProgramData\Keysight\Qcs\Ism\DriverOptions.json

It should have the following contents:

```
[
        {
                "Model": "M5300A",
                "Options": "MonitorTemperature=0, IgnoreAlignmentTempRange=1"
        },
        {
                "Model": "M5301A",
                "Options": "MonitorTemperature=0, IgnoreAlignmentTempRange=1"
        },
        {
                "Model": "M5200A",
                "Options": "MonitorTemperature=0, IgnoreAlignmentTempRange=1"
        },
        {
                "Model": "M5201A",
                "Options": "MonitorTemperature=0, IgnoreAlignmentTempRange=1"
        },
        {
                "Model" : "M9046A",
                "Options" : ""
        }
]
```

If this is a multi-chassis system, or the Configuration Tool has been previously used:

Change the above DriverOptions.json file on the host controller only, and then run the following configuration tool command on the host controller to update the DriverOptions configuration in Consul.

qcsconfigurecli.exe configure update DriverOptions

Then restart the services to run with the new changes.

qcsconfigurecli.exe service restart ism ism

Note: Not monitoring the temperature during alignment can lead to some channel-to-channel unwanted skew (>50ps) due to clock synchronization issues. These issues are only visible if exceeding the +/- 10ºC range since the first Reset Calibration.

Warm-up procedure during initialization

Each time the system is initialized, the QCS software ensures that all instruments reach thermal stability before proceeding with clock alignment. This guarantees that the alignment is robust, precise, and remains valid within the ±10 ºC range from the reference temperature established during the initial Reset Calibration.

To achieve this, all instruments are equipped with a temperature monitoring mechanism. After powering on the modules, the system automatically detects when each instrument has reached a stable temperature.

The warm-up behavior varies depending on the type of system start:

Startup From Power Cycle

The first startup after a hardware power cycle will take ~20 minutes to warmup. Once thermal stability is reached, the system automatically proceeds with initialization and clock alignment.

If the system has been completely powered off for more than 30 minutes (a “cold start”), temperature stabilization may take longer. Internal Keysight testing shows stabilization times between 20 to 40 minutes, depending on system size and ambient conditions.

Startup from Warm System

Startup when the system is already thermally stable should take 1-4 minutes to warmup

If the operating system is rebooted or the software is restarted without powering down the chassis or modules, the system will detect that all components are already warm. No additional warm-up time is required, and the initialization proceeds immediately.

Startup in Thermally Unstable Conditions

If the system startup occurs in thermally unstable conditions (changes of +/-10 degrees C) that persist for >1 hour, the system warmup will produce a warning:

[warning] Warm up failed: Timed-out!

And then proceed with initialization. In this case, please assess the thermal conditions of the environment as experiment results may be affected by thermal instability.

User Calibration and Operational Temperature Management

Purpose of User Calibration

User Calibration allows users to optimize system performance for their specific setup and environment. It establishes an operational reference temperature used for phase drift compensation and for making sure the drift stays within a limited range.

How It Works

When a Reset Calibration is performed, the system records the temperature as the operational reference. During this process, users characterize their setup and store calibration parameters relevant to their experiments, such as acquisition delays and timing offsets.

Keysight's temperature monitoring tool continuously tracks instrument temperature during operation. If the temperature deviates beyond predefined thresholds (e.g., ±5 ºC, ±10 ºC, ±15 ºC), the system will issue a warning to alert the user of potential drift.

Note: Temperature fluctuations during operation do not invalidate the clock alignment established during system initialization. Once alignment is complete, it remains valid regardless of temperature drift.

However, such drift may still affect instrument behavior (e.g., phase or timing), which is monitored by the system during Program execution and reported to the user.

Example Scenarios

Scenario 1: Initial System Setup

Context: A new system is being installed, or a hardware component has been replaced.
Process:

- Upon power-up, the system begins initialization.
- The temperature monitoring tool ensures the system reaches a stable thermal state. Initialization time may vary depending on how long it takes to reach temperature stability.
- Once stability is confirmed, a Reset Calibration is performed.
- The system records the reference temperature and establishes calibration validity.
- Calibration is valid within a wide temperature range (e.g., > ±10 ºC).
- The system is ready for User Calibration and operation.

Scenario 2: Power Cycle

Context: The system is restarted after a shutdown, with no hardware changes.
Process:

- The system powers on and begins initialization.
- The temperature monitoring tool ensures the system reaches a stable thermal state. Initialization time may vary depending on how long it takes to reach temperature stability.
- No Reset Calibration is required. Previously stored calibration data remains valid.

Scenario 3: Operating System Reboot

Context: The operating system is rebooted, but the system hardware remains powered and warm.
Process:

- The system reinitializes without requiring full thermal stabilization.
- Calibration data remains valid.
- Initialization completes quickly, as temperature is already stable.
- No Reset Calibration is required.
- System resumes operation with minimal delay.

Scenario 4: OS Reboot with Temperature Drift

Context: After rebooting the operating system, the system temperature has drifted outside the valid range of the Reset Calibration reference. This range is wide (+/- 10 ºC), so this is probably caused by an important room temperature change or other environmental effects.

Process:

- The alignment process detects that the current temperature exceeds the valid calibration range.
- The system prompts the user to either:
  - Take action to ensure room temperature is stable and gets closer to the initial reference temperature
  - Perform a new Reset Calibration if the new temperature is expected to remain stable
  - Disable the temperature checks during the alignment

Scenario 5: Operational Temperature Drift During Experiment

Context: The system is running a long-duration experiment, and the temperature fluctuates by more than +/- 10 ºC in one of the instruments.

Process:

- The temperature monitoring tool detects that the temperature during operation moved outside of the +/- 10 ºC range.
- The user is notified that data quality may be affected due to excessive drift.
- The ongoing Programs are not interrupted and those in the queue will keep running unless manually stopped.
- The system prompts the user to either:
  - Take action to ensure room temperature is stable and goes back to the User Calibration reference temperature.
  - Recalibrate (User Calibration) the system at the new stable temperature.