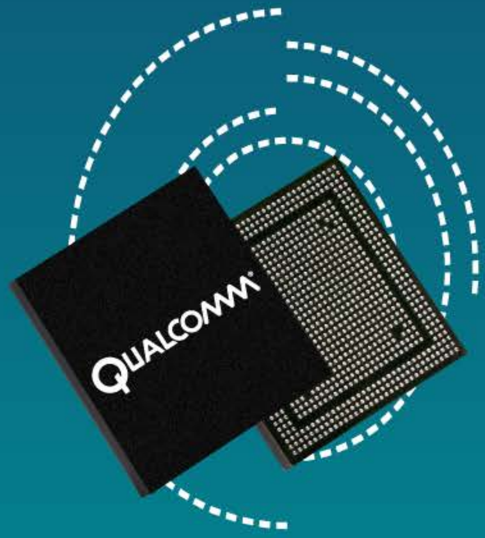
Qualcomm Technologies, Inc



Thermal Tuning Procedure

80-N9649-1 C

Qualcomm Technologies, Inc.
5775 Morehouse Drive
San Diego, CA 92121
U.S.A.

Revision History

Revision	Date	Description
A	Feb 2012	Initial release
B	Feb 2013	Numerous changes were made to this document; it should be read in its entirety.
C	Mar 2014	Added software thermal requirement/sanity check, tuning procedures for dynamic algorithms and thermal calibration procedure for speaker coil protection. This doc is only for the **thermal-engine**-based solution.

Contents

Thermal Tuning Overview

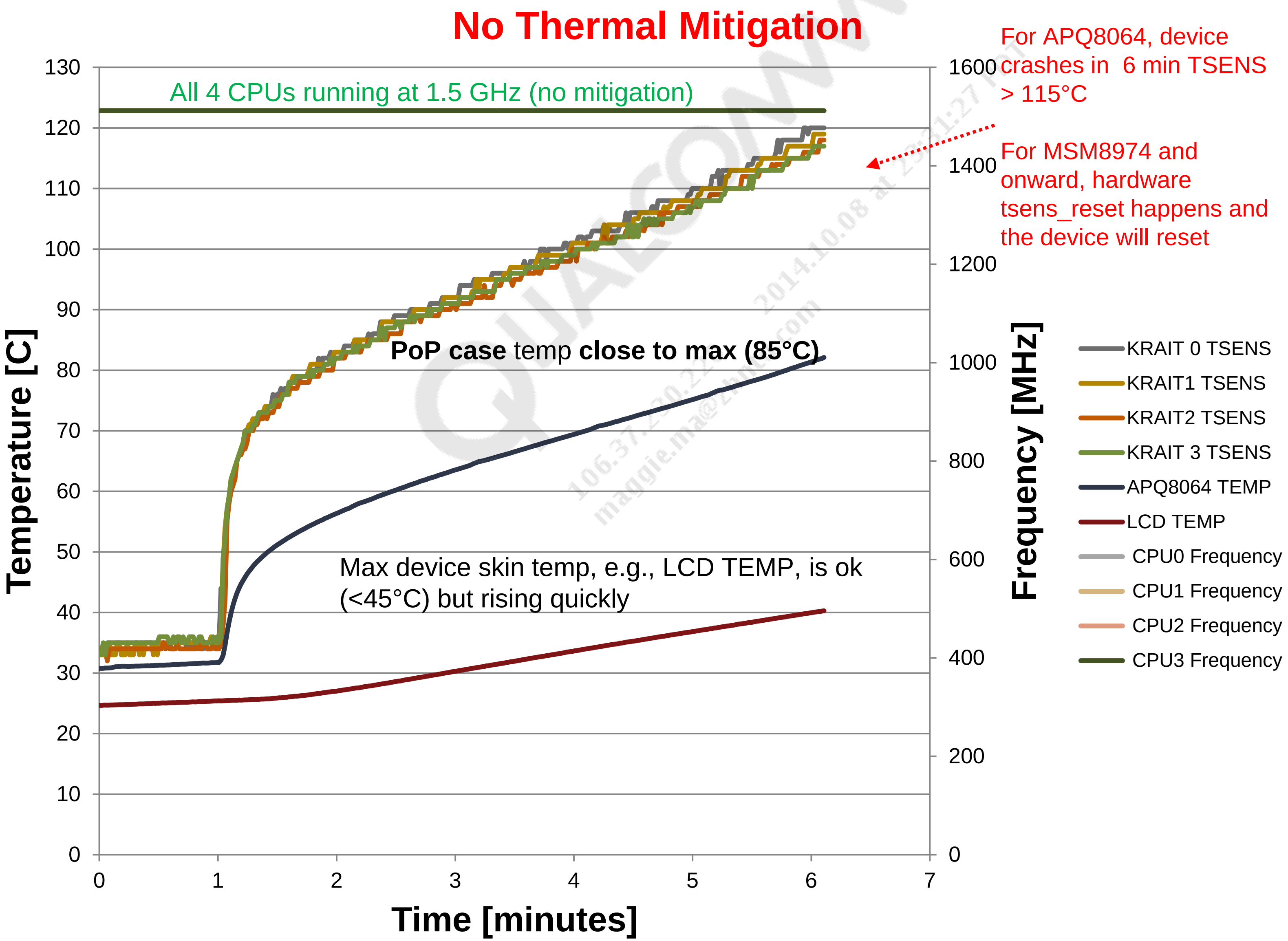
Thermal Tuning − Software

- What it is
  - Optimizing the default thermal configuration file based on device testing; the goal is to enable maximum CPU, GPU, Modem, Camera, etc. performance without compromising thermal limits of the chipset components or the device.
- Why it is needed
  - To ensure the Thermal Mitigation Algorithm performs optimally for a given mechanical/industrial design (MD/ID)

    Note: Once the MD/ID is defined, software thermal mitigation is the last remaining method to manage heat generation.

  - This will allow the device to operate at highest frequency, fps, and data rates for as long as possible before thermal mitigation begins to reduce performance.
- When it is needed
  - Thermal tuning needs to be performed as soon as Feature Complete (FC) software is available on chipsets that have open-loop AVS (also known as PVS) settings. Waiting too long to verify thermal Key Performance Indicators (KPIs) may result in the delay of the customer launch. Starting too early (without open-loop AVS enabled or without FC software) may result in damaged devices or unnecessary time wasted in thermal and power debug.
- The following slides show the result of thermal mitigation thermal tuning.

APQ8064+MDM9615 MTP Running Quad Dhrystone



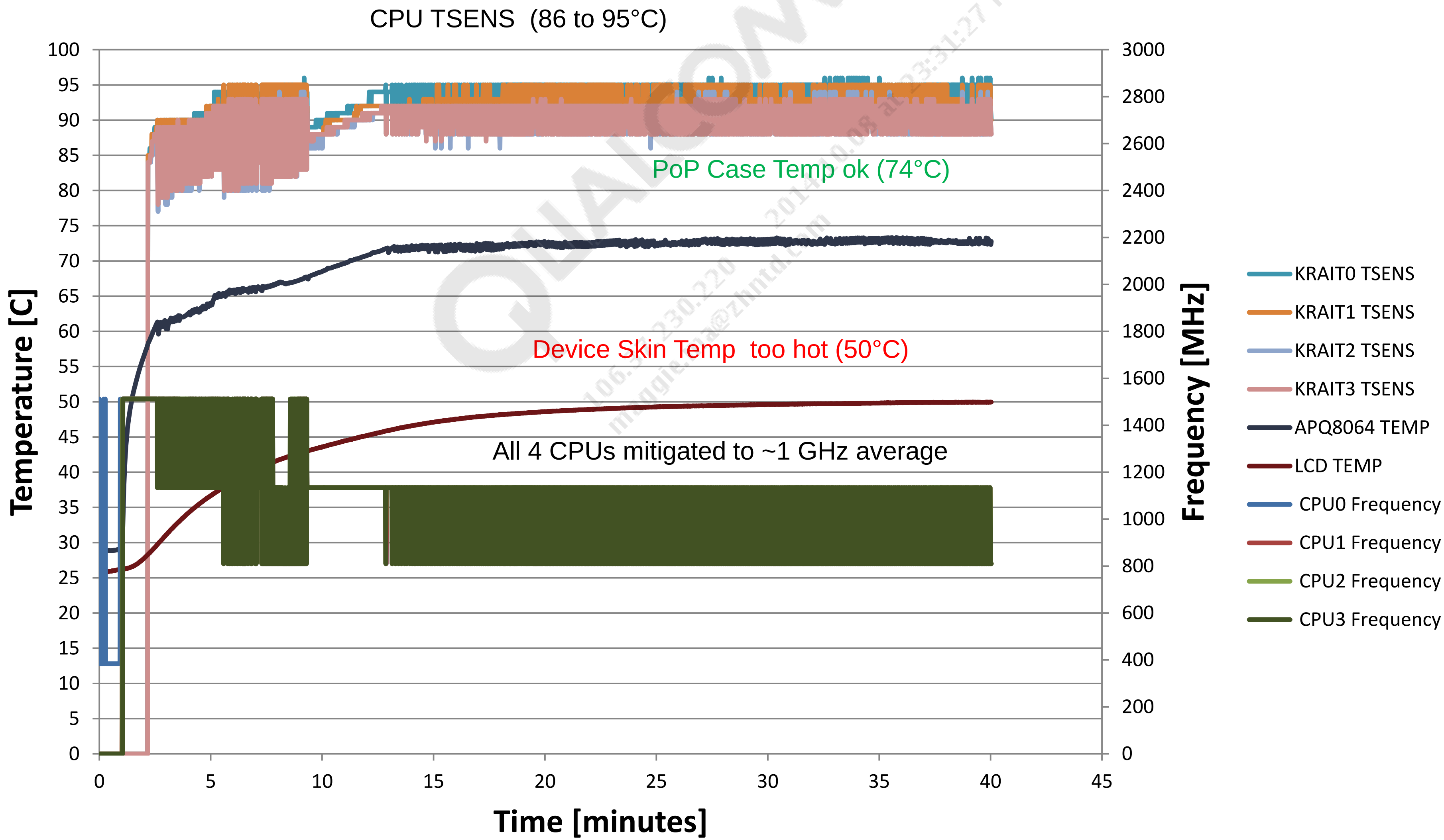
For APQ8064, device crashes in 6 min TSENS > 115°C

For MSM8974 and onward, hardware tsens_reset happens and the device will reset

APQ8064+MDM9615 MTP Running Quad Dhrystone (cont.)

Thermal Mitigation Enabled

No Thermal Tuning – (Using default Thermal-engine.conf file)

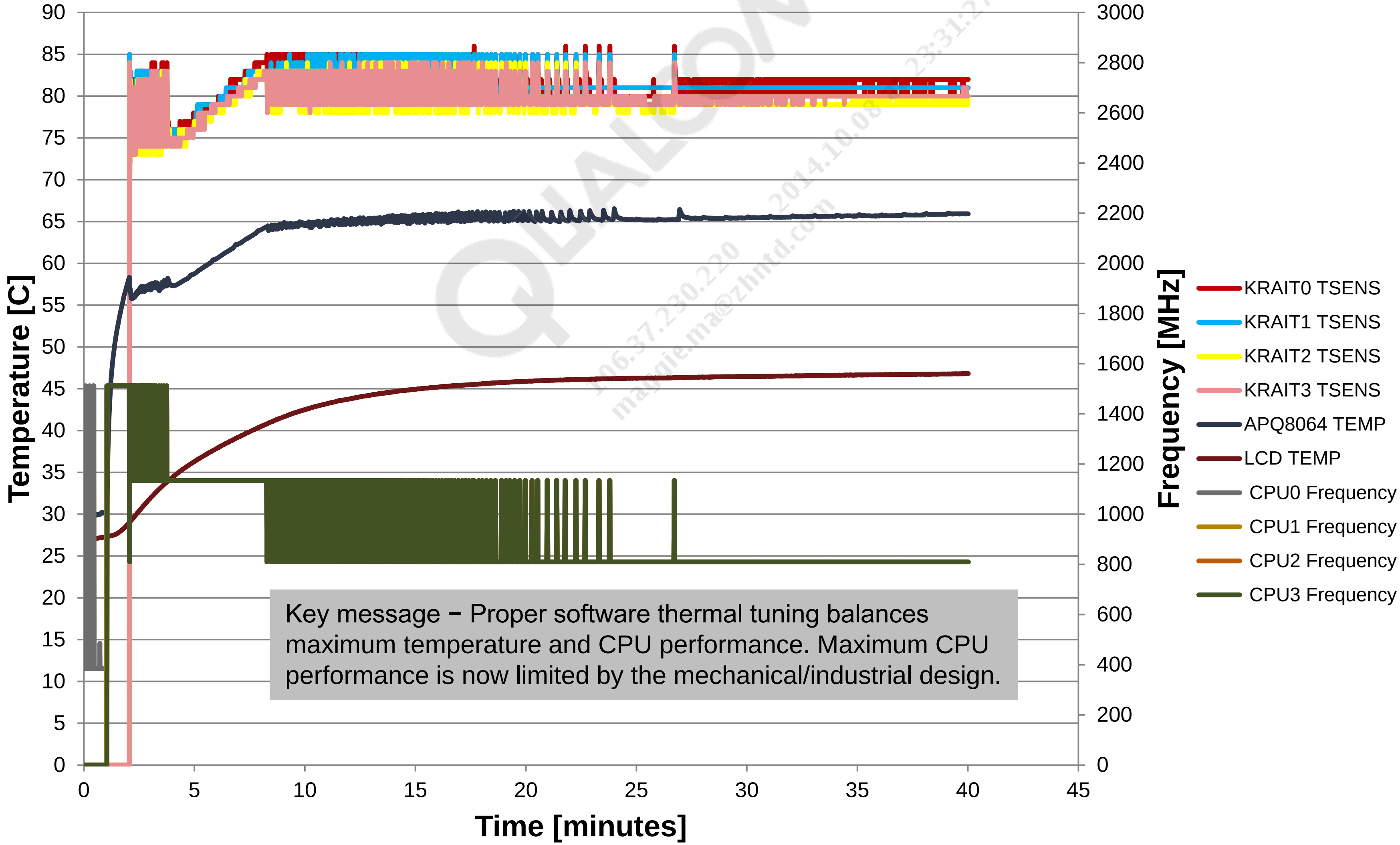


 80-N9649-1 C Mar 2014

APQ8064+MDM9615 MTP Running Quad Dhrystone (cont.)

Thermal Mitigation Enabled

Thermal Tuning Enabled – (Modified Thermal-engine.conf file)



Key message − Proper software thermal tuning balances maximum temperature and CPU performance. Maximum CPU performance is now limited by the mechanical/industrial design.

Key Factors

- Key factors required for performing thermal tuning
  - PCB installed with all component shields into the final device skin; battery installed
  - Qualcomm Technologies, Inc. (QTI) devices with open-loop AVS enabled
    - Attempts to do thermal tuning with initial ES devices (open-loop AVS not enabled) may result in exceeding device specification maximum case temperatures, system crashes, and damage to the device. See the Device Revision Guide to determine which devices are appropriate to use for thermal tuning.
  - QTI FC software
    - Thermal stress testing is used to identify hotspots on the Device Under Test (DUT) skin.
    - Attempts to do thermal tuning with non-FC software may result in exceeding device specification maximum case temperatures, system crashes, and damage to the device. See the AMSS Release Notes to determine which builds are appropriate to use for thermal tuning.
  - Proper test setup
  - Proper test procedure

Note: The MD/ID design characteristic of each form factor has the most effect on the device's overall performance.

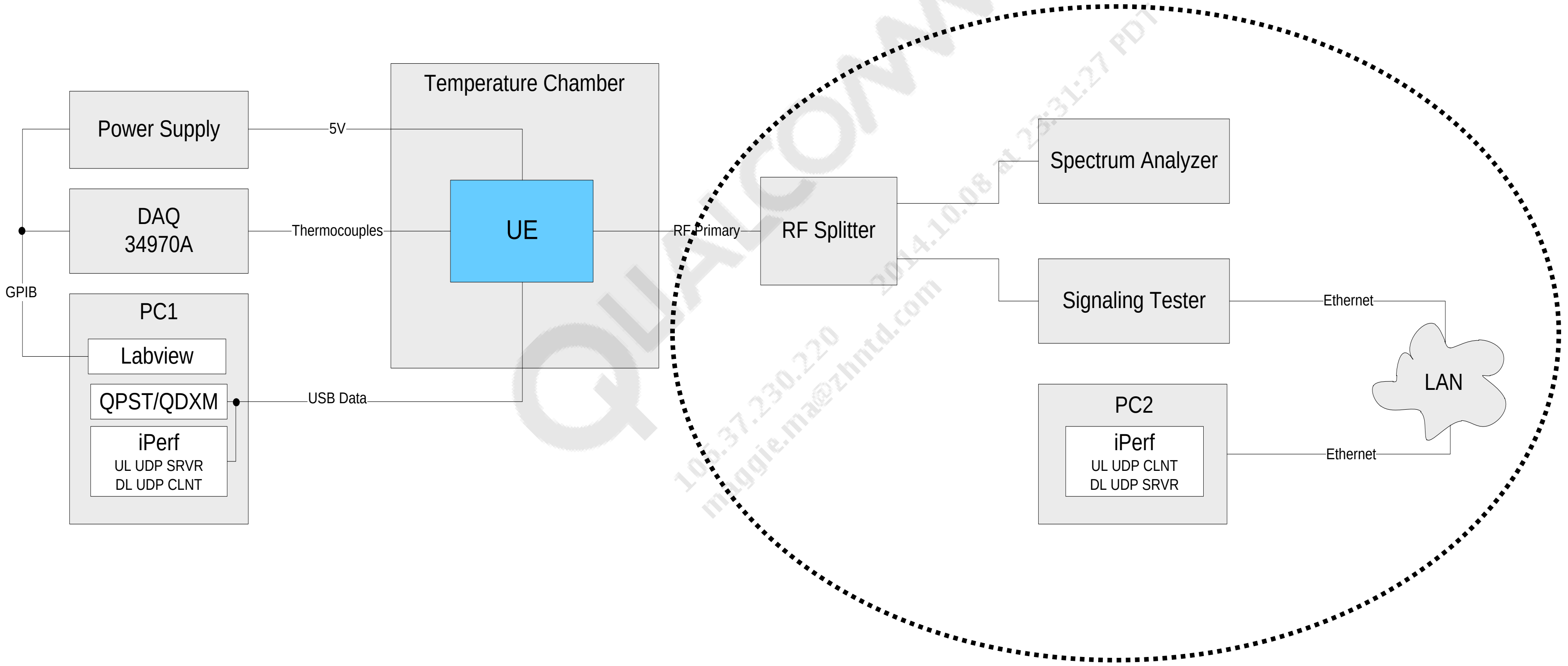
Thermal Test Setup

Thermal Lab Setup

- Purchase thermal lab-related materials.
  - Data acquisition equipment as described below
  - Other required thermal equipment needed
- Set up the environment.
  - Place your device in a mechanical vice.
  - Insert a Micro SD card.
    - This is required to run the glBenchmark 2.5 Egypt HD in a fixed frame loop.
  - Disable USB charging (leave the USB plugged in).
  - Set the screen timeout to NEVER.
  - Set the display to maximum brightness.

Test Setup

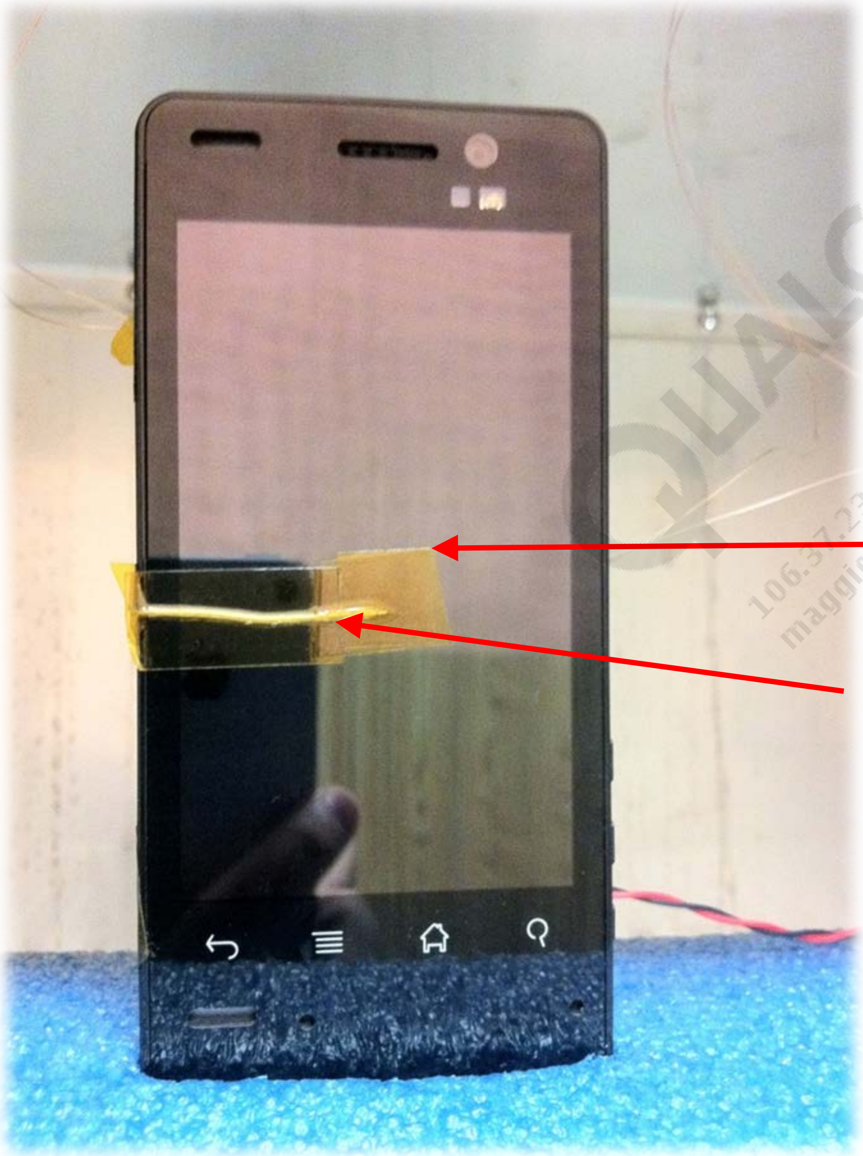
Required for modem-centric thermal use cases



Placement of Hotspot and Skin Thermocouples

- Verify whether a thermocouple has a break/open *before* you begin.
  - Use a digital multimeter with a temperature setting. Connect each probe to each of the two dissimilar metals to verify functionality. The multimeter should read a temperature close to ambient (~25°C).
- Untangle thermocouples and lay them out completely before you begin.
  - Create a label and attach it with Kapton tape along each thermocouple.
  - Place your device in a styrofoam pad or any holding structure with insulation between the chamber and DUT to secure in an upright position (see slide 18).
- Run a very CPU-intensive application, i.e., Dual Dhrystone, at maximum CPU frequency for a few minutes to identify hotspots on LCD and back cover.
  - Use only QTI devices with open-loop AVS settings and FC software.
  - Continuously runs for the period with no crashes.
- With the application running, monitor the Device Skin with an IR camera and find the hotspot (hottest point), e.g., on APQ8064+MDM9615 MPT, this is on the LCD itself.
  - Place the thermocouple tip on the exact hotspot and place a few pieces of Kapton tape over it. The tape should cover the length of the thermocouple.
  - Monitor the back cover with the IR camera to find the hotspot.
  - Place the thermocouple tip on the exact hotspot and place a few pieces of Kapton tape over it. The tape should cover the length of the thermocouple.
- Power down and allow the device to cool back to ambient temperature.

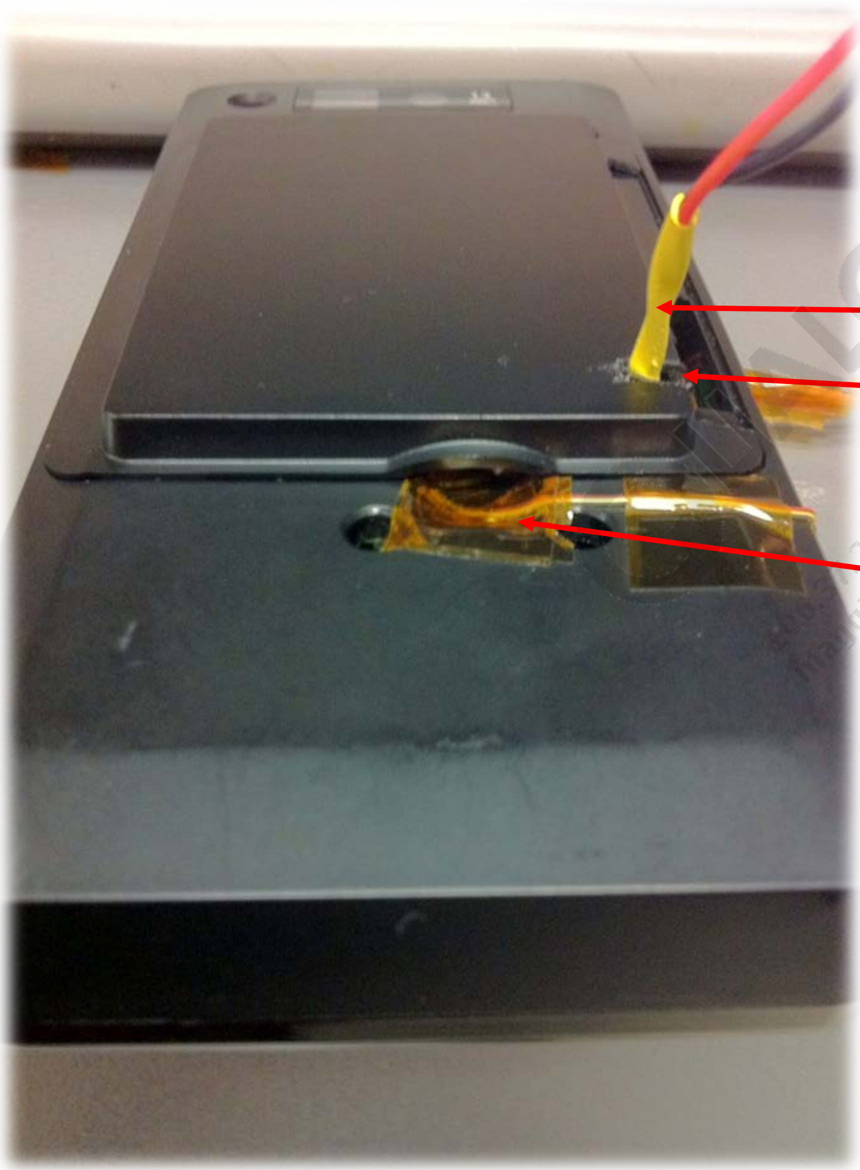
Proper LCD Thermocouple Placement



Layers of Kapton tape to hold thermocouples in place

Thermocouple

Proper Backside Thermocouple Placement



Fake battery leads

Hole cut into housing for fake battery leads

Back cover thermocouple with Kapton tape

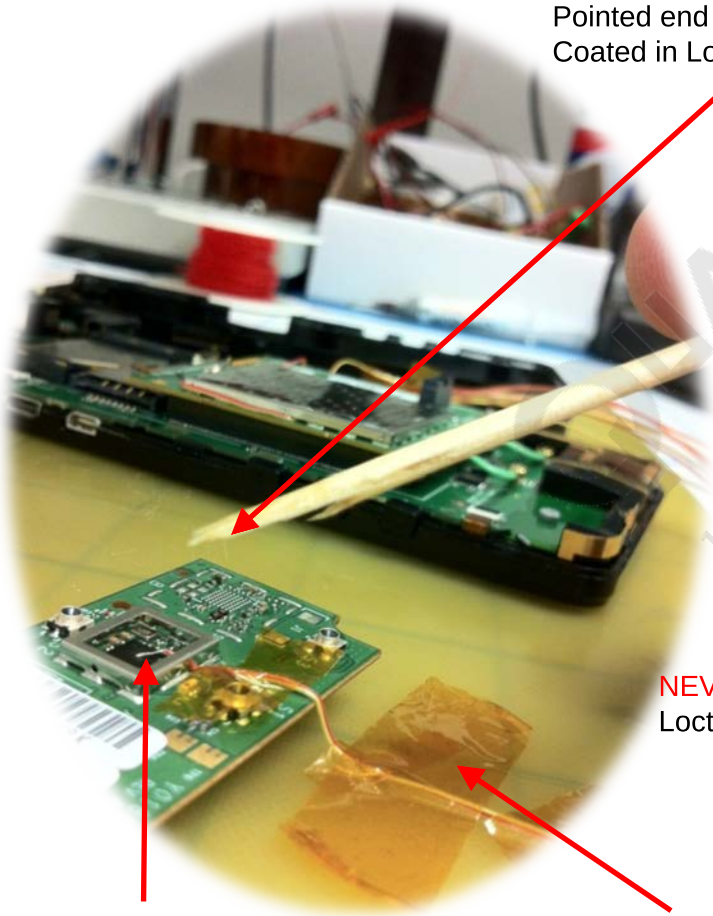
Placement of Internal Thermocouples

1. Completely disassemble your DUT. Remove the PCB from the housing assembly.
2. Plan your thermocouple routing before you begin.
3. Using the IC package mechanical specs, find the exact middle of the device.
4. Place the thermocouple at that spot. It is very important that it is exactly in the middle and that it maintains complete contact with the component. Place each thermocouple flat against the board when you route, using the Kapton tape to securely hold it in place.
   - 36 AWG is thicker and more durable than 40 AWG but it needs more space and may not be routed underneath some shielding.
   - Decide before placement; 40 AWG is fragile and if broken will completely ruin your work once bonded with Loctite 444.
5. With tweezers grab the thermocouple shielding at the junction.
6. Make a crimp on the junction so it is no longer straight across but curved slightly downward.
   - It must be pointing downward so that when you place the Kapton tape around it, the thermocouple is able to touch the PoP memory on its own. Make sure the tip is in the exact middle and touching the component (see the next slide).
7. Use a microscope to verify.
8. Route cables so they make as little contact with other components as possible. Permanent mechanical rework may be necessary (cutting shielding bars or back cover of housing).

Note: You may flatten the body of the thermocouple after it is secured to the component (glue must be cured using the accelerant). The tip should *not* move.

Placement of Internal Thermocouples (cont.)

GOOD

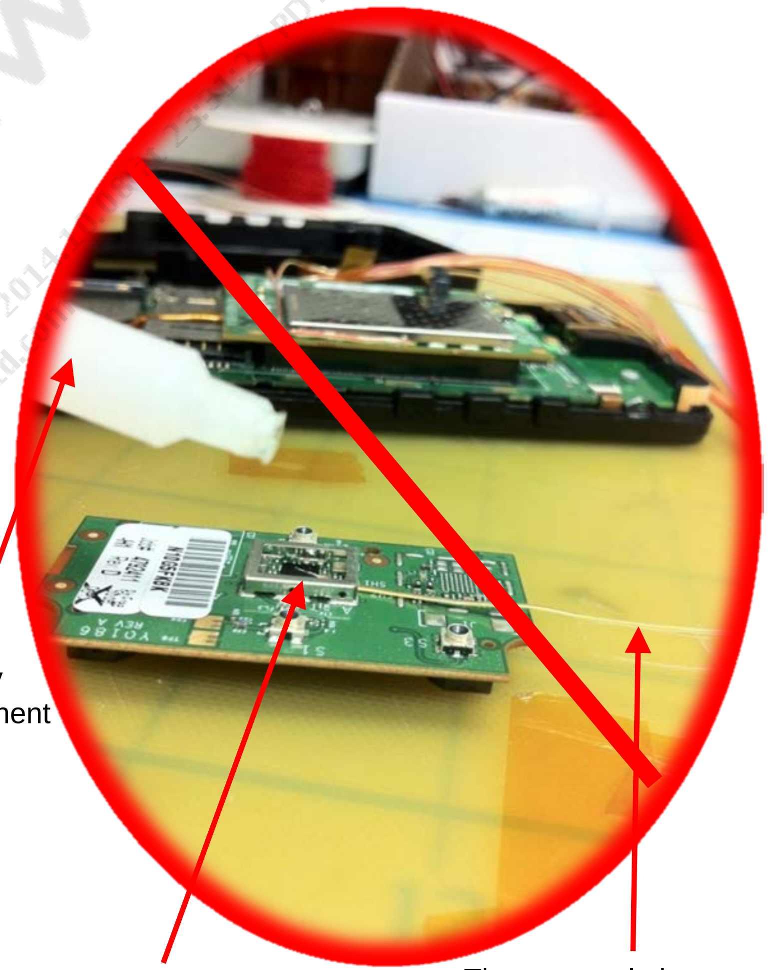


Pointed end of swab
Coated in Loctite 444

Junction bent downward to make complete contact with component

Kapton tape secures thermocouple

BAD



NEVER directly apply Loctite 444 to component

Junction is up in the air, and it is straight across; not bent downward

Thermocouple is not secured; very loose

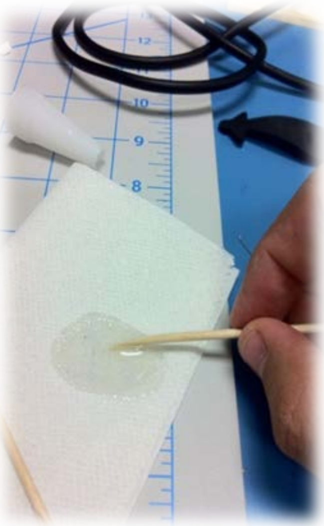
Placement of Internal Thermocouples (cont.)

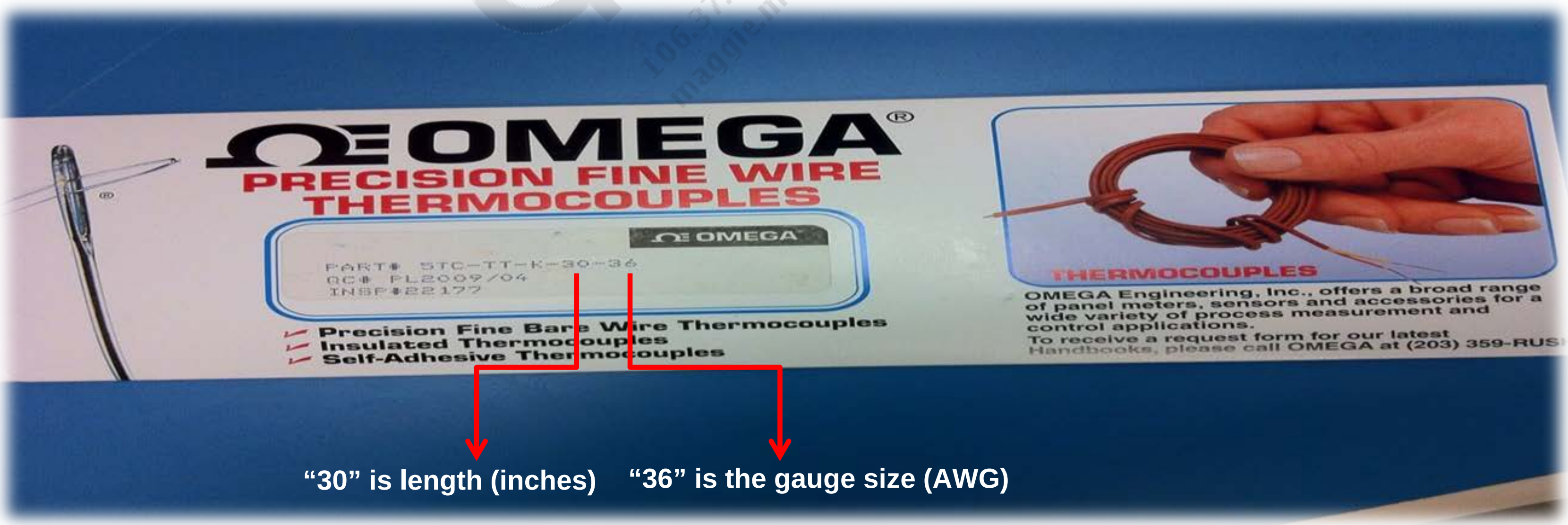
9. After your thermocouple is secured with Kapton tape and makes complete contact with the exact middle of the component package:
   a. Squeeze Loctite 444 onto a clean piece of paper.
   b. Snap your wooden cotton swab in half, take the pointed end and coat by rolling its edge in Loctite 444 (see next slide).
   c. **Use a microscope for the rest of the procedure.**
   d. Place the smallest possible amount on the tip and the area where it touches the component. It should look like a small bubble under a microscope.

      <u>This is extremely important</u>. There must only be enough to hold the thermocouple tip rigidly in place (even if the device must be constantly moved). After applying Loctite 444, there must be ***NO space*** between the thermocouple tip and the package.

      If it <u>must</u> be reworked, scrape off the thermocouple, replace, and find another location. This may not be possible to remove depending on the bond. It is best to start off with a brand new thermocouple. The prior location is ruined and ***<u>cannot be used again</u>*** for thermocouple placement. Loctite cannot be removed without destroying the PCB.
   e. Immediately open your accelerator fluid and very slightly touch the Loctite 444 on the thermocouple/ component with the brush. This will quickly accelerate the curing process.
   f. Carefully remove the Kapton tape.
   g. Make sure the thermocouple junction (that is not covered by glue) does not come into contact with metal, i.e., PCB shield, before reassembly.
   h. If needed, place thermocouple against the board and add Loctite 444 so it is secured to the PCB. This will strengthen the overall bond of the thermocouple (see slide 13).
   i. Place thermocouples in as many other locations as desired.
   j. If more than one thermocouple is used internally, route all to the same exit point *tightly* as close as possible and secure the outer bundle with the Kapton tape rolled around it, zip-tie, or both.

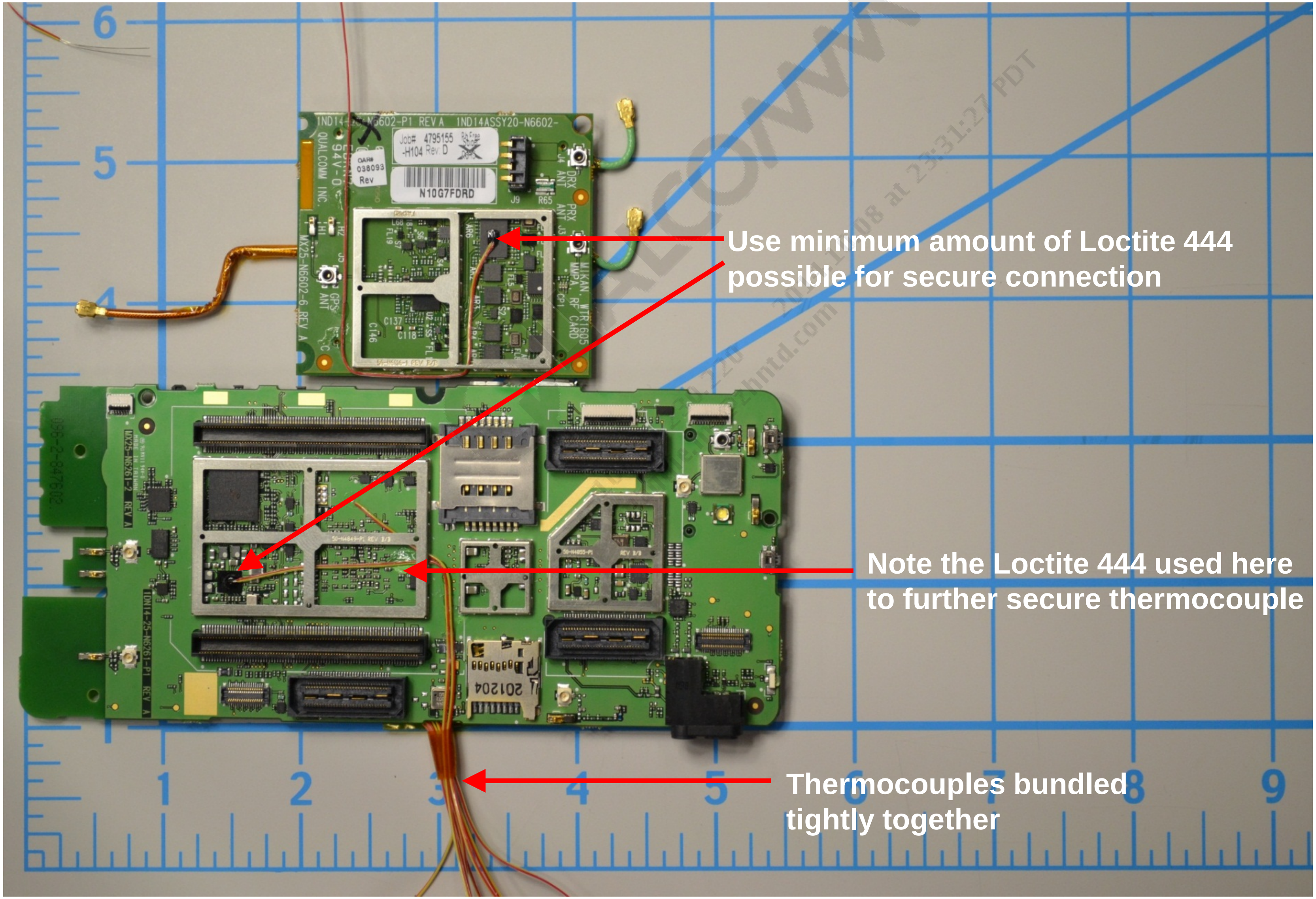
Thermocouple Materials



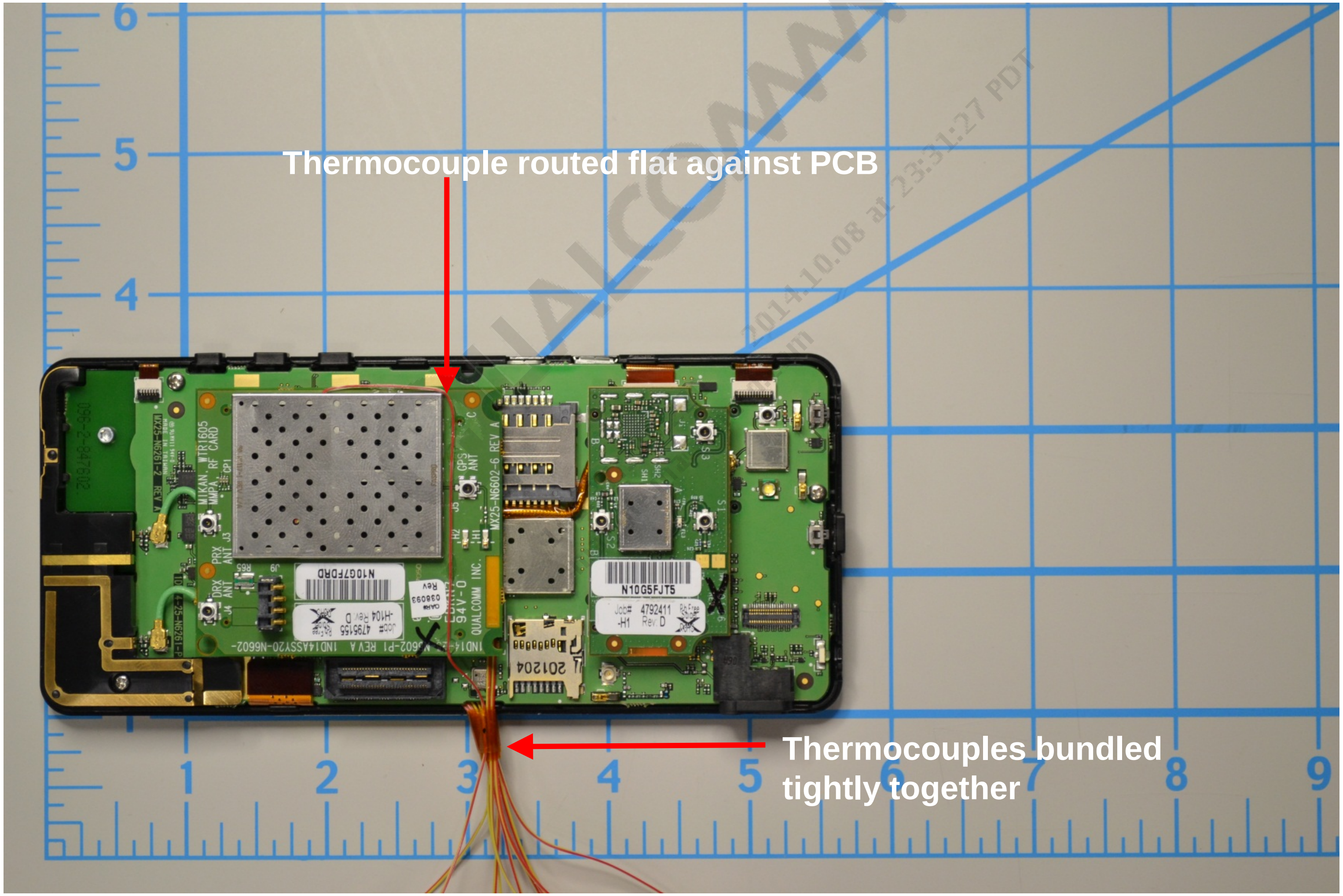


Omega K-Type 36 AWG 30” Thermocouples (pack of 5)

Internal Thermocouple Attachment



Thermocouple Routing



Reassembly and Data Logger

1. Reassemble PCB with the housing assembly and secure all connections.
   - It may be necessary to cut a hole into the bundle exit point on the front or back housing. You do not want to snap the assembly together on the thermocouple as it may break and destroy your work!
   - Do not yet bundle the rest of the thermocouples together.
   - Decide in which order you want the thermocouples to be placed in the Data Logger. Write down this order of placement.

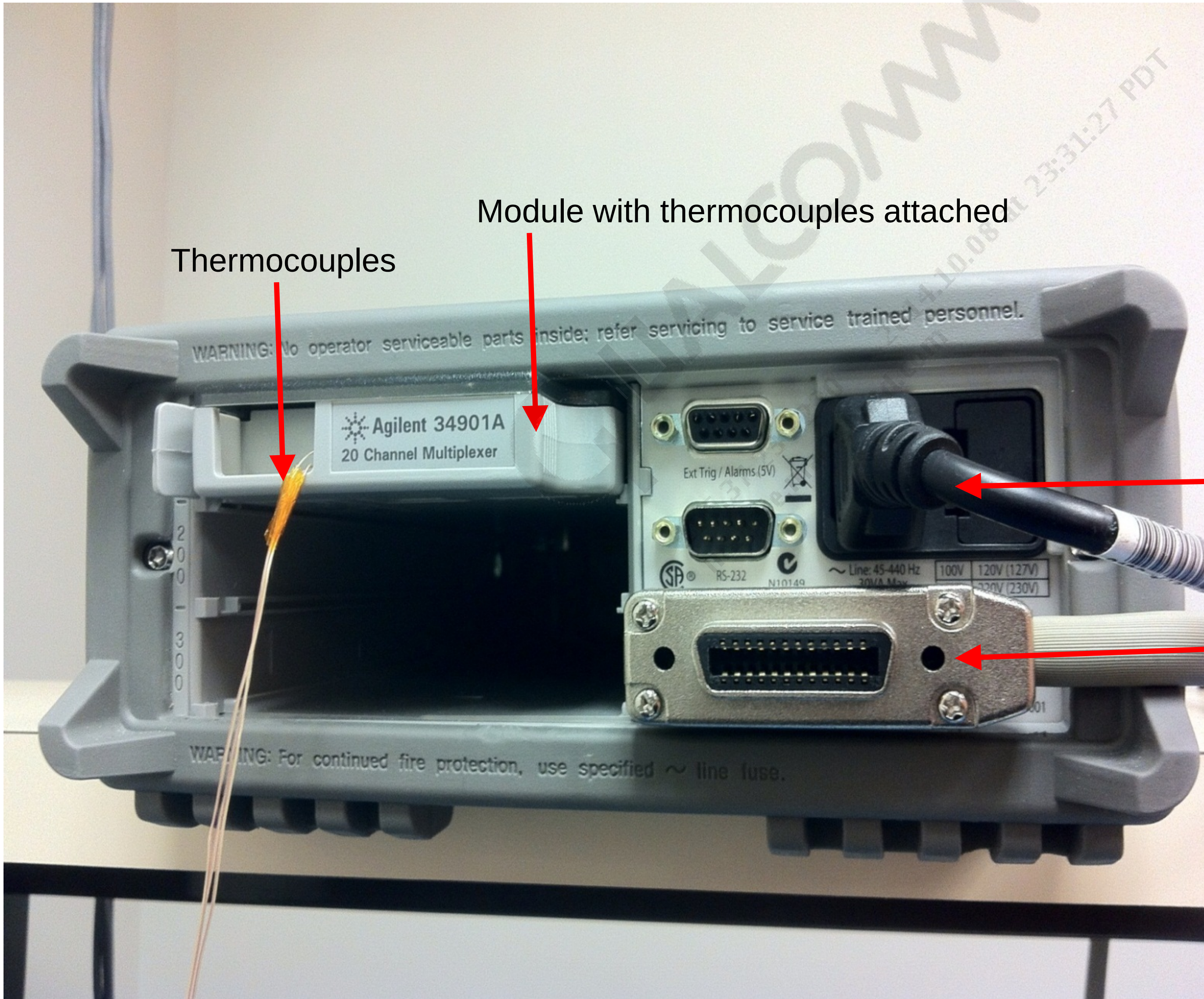
   Note: Also see *Getting Started Guide* from Agilent.

2. Open data logger 20-channel multiplexer cover with a screwdriver or pen, pushing the latch forward (be careful or you will need to replace the module).
3. With the correct mini flathead screwdriver, unscrew applicable screws in the Agilent multiplexer module.
   - Below each screw is an opening to which you place the metal end of the thermocouple. Each opening contains a piece of metal that secures the thermocouple in place.
   - Unscrew until you see this piece of metal go completely down.
   - Each channel in the multiplexer is labeled with an H (HI) and an L (LO). The yellow end of the thermocouple is HI, red is LO.
4. It is easier to insert both ends at once, holding the body of the thermocouple with one hand and use a mini screwdriver until the metal piece goes up and secures the thermocouple in place.
5. Do the same for the other lead while still holding the body with one hand.
6. Repeat for all thermocouples.

Verification and Common Setup Errors

- Verify with a digital multimeter
  - Place your hot and ground leads separately, with one for HI and the other for LO, for each channel. Polarity is not considered, i.e., positive lead contacts the screw at CH01 HI, and ground lead contacts the screw at CH01 LO.
  - Only place multimeter leads at the screws, *not* at the thermocouples themselves.
  - You are only verifying that you see a temperature reading.
  - Also check that the yellow lead is the first in the channel.
  - If there is an OPEN reading, then your thermocouple HI and LO may not be in the same channel. Extract and correct.
  - It also may indicate a break in your thermocouple, which ruins your work and must be replaced.
  - If temperature readings on data logger jump around, it may indicate a loose thermocouple. Extract and correct.

Agilent Data Logger (with 20-Channel Multiplexer Module)



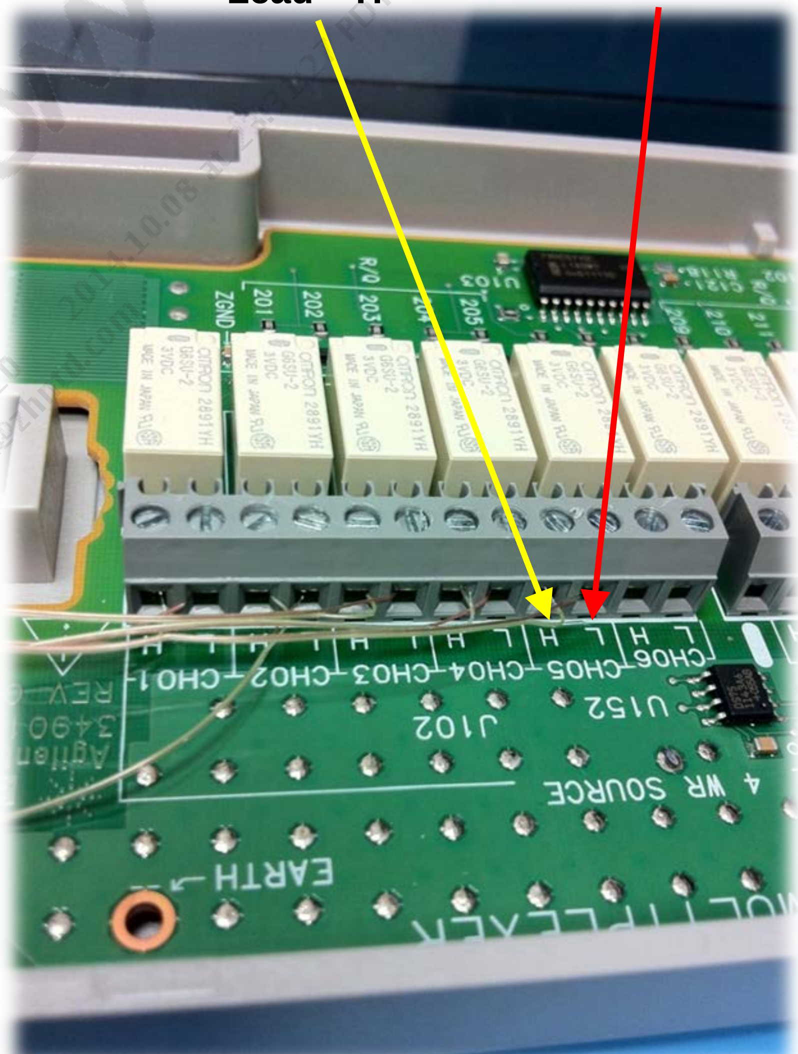
Power cable

GPIB connection (GPIB from Data Logger to Expansion Card in PC)

20-Channel Multiplexer Modules (Data Logger)

Yellow or light Lead = H

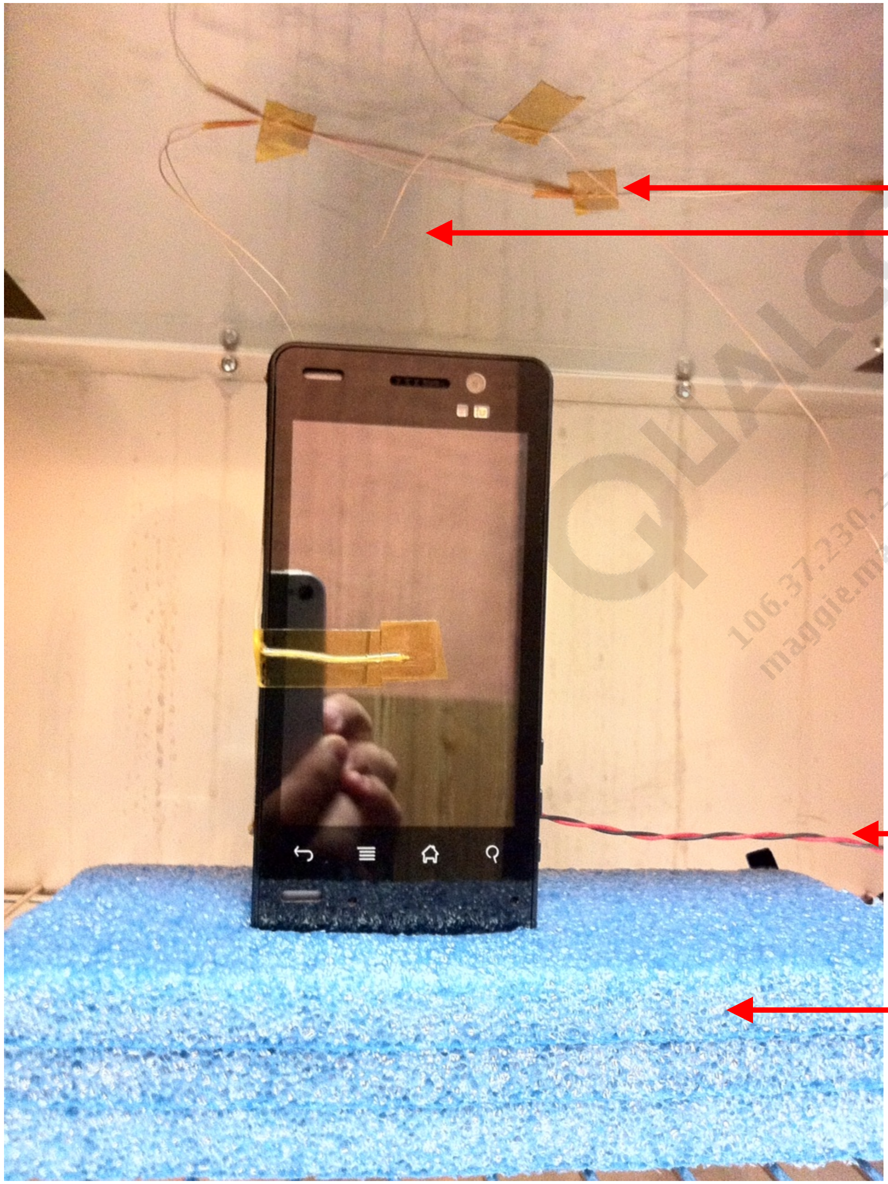
Red or dark Lead = L



Temperature Chamber Setup

1. Use a large temperature chamber that has the ceiling clearance to hold your PanaVise (a holding/clamping tool) and DUT, with ambient thermocouple hanging down 1 in. above the device. If not, use a styrofoam block, then cut out an area of the styrofoam so that you can place the device to secure it upright (it also works if you want to rest it in landscape orientation).
2. Place fake battery, device with thermocouples, and USB cable inside the chamber.
3. Turn on the temperature chamber and set the temperature to 25°C.
4. Turn off the air flow before you are ready to test.

Temperature Chamber Setup (cont.)



Thermocouples taped to ceiling

Thermocouple measures ambient temp
(~1 in. away from DUT and possibly place it on one side of DUT)

Fake battery leads from DUT to power supply

Styrofoam pad or any holding structure with insulation between the chamber and DUT

Data Logger Application

1. Insert as many multiplexer modules as you want to have available into Data Logger (maximum of 3, minimum of 1).
2. Click **Configuration→New**. Label this configuration.
3. Select **Application Mode→Connected to Instrument**.
4. Select **Add or Remove Instruments→Add Instruments.**
   - Click **Find Instruments**.
   - A search will begin for your module. Once it has correctly found your module(s), check the box and click **Enter**.
5. Below will appear 34901A: 20-Channel Armature Multiplexer.
6. The top module compartment is 100, middle is 200, and bottom is 300 on Data Logger.
7. Check the boxes under the Scan column for the number of thermocouples you wish to monitor.
8. The order of thermocouples must correspond to the exact order in the module, e.g., 101 – LCD, channel 01 in module must have the HI and LO leads of the thermocouple connected to the LCD.
9. Select the space corresponding to the desired channel under the Name column, and give your thermocouple a name.

Note: Some of this information is available in the Benchlink Data Logger 3 Getting Started Guide.

Data Logger Application (cont.)

10. In the Function column, select **Temp (Type K)** for Type-K thermocouples. Verify that it shows C (Celsius) in the Res column.
11. You at least need four thermocouples, one for LCD at CPU, back cover, internal thermocouple on PoP memory, and ambient.
12. The Scan and Log Data tab should now be populated with the information given in step 11.
13. In the same tab, under Scan Control heading, click **…** under the Set column.
14. In this dialog box, select Immediately, make sure Interval (Time Between Scans) under SS: is 1. Also select the By Pressing Stop Scan Button for Stop Scanning option. Click **Apply to all instruments** at the bottom.

Note: Some of this information is available in the Benchlink Data Logger 3 Getting Started Guide.

Prerequisite – Thermal Software Requirements and Sanity Checks

Thermal Requirements and Sanity Checks

- Software thermal requirements
  - QTI thermal software and OEM-specific thermal software should handle all the thermal threats from the boot.
  - QTI strongly recommends that the following software components need to be enabled properly all the time:
    - Boot Thermal Monitor (BTM) – Optional
    - Kernel Thermal Monitor (KTM) – Mandatory
    - Thermal engine with proper configuration file – Mandatory unless OEM incorporates third-party thermal management software with equivalent functionality
- Thermal software sanity check
  - Verify internal/external sensor calibration
  - Verify BTM
  - Verify KTM and kernel level emergency throttling
  - Verify any unintended performance boosting mechanisms
  - Verify full thermal software
  - The following slides show how to perform the basic checks before thermal tuning

Verification – Thermal Sensors

- Thermal sensors
  - Internal TSENS
    - Depending on chipsets, up to 11 internal TSENS sensors are located on or around hotspots on the MSM™/APQ/MDM.
    - All the TSENS sensor values are accessible through kernel TSENS driver and exposed to sysfs nodes for user space accesses.
      - cat /sys/devices/virtual/thermal/thermal_zone[A-B]/temp, where A and B are numbers and varies with chipset and configuration
  - External thermistors
    - OEM-specific but generally most external sensor nodes are exposed to sysfs nodes.
    - For thermistors connected to PMIC ADC, available sysfs nodes are:
      - cat /sys/devices/virtual/thermal/thermal_zone[C-D]/temp, where C and D are numbers and varies with chipset and configuration
- Check thermal sensor calibration status
  - Place the DUT into the temperature chamber at 50°C.
  - Ensure that thermal mitigation is disabled and the device needs to be idling.
  - Soak for at least 30 min.
  - Read all the sensor values and thermocouples, the temperature value should be 50°C with reasonable variations (±1.5ºC for TSENS).

Verification – BTM Functionality

- Verify BOOT_TEMP_CHECK_THRESHOLD_DEGC is defined in boot loader.
- The boot procedure will be delayed by MAX_TEMP_CHK_ITER*MAX_WAIT_TIME_MICROSEC ms, which is defined at /core/boot/secboot3/src/boot_thermal_management.c
- Only when the temperature is not within the following two limits hardcoded at /boot_images/core/hwengines/tsens/config/8974 (target name)/BootTempCheckBsp.c:

```
const BootTempCheckBspType BootTempCheckBsp[] = {
   {
      /* .nUpperThresholdDegC */ 150,
      /* .nLowerThresholdDegC */ -150
   }
};
```

- Check BTM functionality.
  - Change nUpperThresholdDegC to 40°C and recompile and load the new image.
  - Place the DUT into the temperature chamber at 50°C.
  - Soak for at least 30 min and try to boot the device.
  - If the device does not boot, which is a correct action, then cool down the device at room temperature at least 30 min and try to boot the device again; the device needs to boot correctly.
  - Reiterate the test for low temperature case by updating nLowerThresholdDegC as well if required.

Verification – KTM Functionality

- Verify KTM thermal configuration and operation with kernel message
  - Defined at qcom,msm-thermal section in dtsi file (device tree) for respective chipsets; following is an example for MSM8974

```
qcom,msm-thermal {
        compatible = "qcom,msm-thermal";
        qcom,sensor-id = <5>;
        qcom,poll-ms = <250>;
        qcom,limit-temp = <60>;
        qcom,temp-hysteresis = <10>;
        qcom,freq-step = <2>;
        qcom,freq-control-mask = <0xf>;
        qcom,core-limit-temp = <80>;
        qcom,core-temp-hysteresis = <10>;
        qcom,core-control-mask = <0xe>;
        qcom,hotplug-temp = <110>;
        qcom,hotplug-temp-hysteresis = <20>;
        qcom,cpu-sensors = "tsens_tz_sensor5", "tsens_tz_sensor6", "tsens_tz_sensor7",
        "tsens_tz_sensor8";
        qcom,freq-mitigation-temp = <110>;
        qcom,freq-mitigation-temp-hysteresis = <20>;
        qcom,freq-mitigation-value = <960000>;
        qcom,freq-mitigation-control-mask = <0x01>;
        qcom,vdd-restriction-temp = <5>;
        qcom,vdd-restriction-temp-hysteresis = <10>;
        qcom,pmic-sw-mode-temp = <85>;
        qcom,pmic-sw-mode-temp-hysteresis = <75>;
        qcom,pmic-sw-mode-regs = "vdd-dig";
        vdd-dig-supply = <&pm8841_s2_floor_corner>;
        vdd-gfx-supply = <&pm8841_s4_floor_corner>;
```

Some features are only for MSM8974 and later chipsets

Verification – KTM Functionality (cont.)

- Verify KTM thermal configuration and operation with kernel message (cont.)
  - Defined at qcom,msm-thermal section in dtsi file (device tree) for respective chipsets; the following is an example for MSM8974 (cont.)

```
qcom,vdd-dig-rstr{
        qcom,vdd-rstr-reg = "vdd-dig";
        qcom,levels = <5 7 7>; /* Nominal, Super Turbo, Super Turbo */
        qcom,min-level = <1>; /* No Request */
};
qcom,vdd-gfx-rstr{
        qcom,vdd-rstr-reg = "vdd-gfx";
        qcom,levels = <5 7 7>; /* Nominal, Super Turbo, Super Turbo */
        qcom,min-level = <1>; /* No Request */
};
        qcom,vdd-apps-rstr{
        qcom,vdd-rstr-reg = "vdd-apps";
        qcom,levels = <1881600 1958400 2265600>;
        qcom,freq-req;
};
};
```

Some features are only for MSM8974 and later chipsets

Verification – KTM Functionality (cont.)

- Verify KTM frequency mitigation
  - Reduce the threshold and see if CPU mitigation happens through kernel message
    - Update qcom,limit-temp = <40>; and recompile and load the new image.
    - Reboot the device.
    - Every sampling period (qcom,poll-ms = <250>), CPU frequency is being throttled down to min (keyword: msm_thermal).
      - <6>[2.243338] msm_thermal: Limiting cpu0 max frequency to 384000
      - <6>[2.243338] msm_thermal: Limiting cpu1 max frequency to 384000
      - <6>[2.243338] msm_thermal: Limiting cpu2 max frequency to 384000
      - <6>[2.243369] msm_thermal: Limiting cpu3 max frequency to 384000

Verification – KTM Functionality (cont.)

- Verify KTM thermal emergency throttling (for MSM8974 and later chipsets only).
  - CPUs are hotplugged when temperature exceeds the threshold (qcom,freq-mitigation-temp = <110>) and brought back if the temperature lowers back down (qcom,freq-mitigation-temp = <110> - qcom,freq-mitigation-temp-hysteresis = <20>).
  - Emergency CPU throttling is initiated to mitigate CPU frequency to (qcom,freq-mitigation-value = <960000>) when the temperature exceeds the threshold (qcom,freq-mitigation-temp = <110>), and CPU mitigation ends once the temperature lowers down (qcom,freq-mitigation-temp = <110> - qcom,freq-mitigation-temp-hysteresis = <20>).
- Emergency mitigation protects the system even without thermal engine.
  - Do not run thermal engine (stopping thermal-engine service).
    - #stop thermal-engine from adb shell
  - Run highly stressful apps such as quad-dhrystone, Antutu, or StabilityApp for at least 10 min without TSENS reset (reset from other reasons such as watchdog can still occur).

Verification – Thermal Malware

- There exists various mechanisms which impact thermal characteristics by forcefully altering operating conditions of each component (mostly CPU frequency/GPU frequency/Bus frequency/Power rail voltages).
- Beware of the following which can impact thermal behaviors:
  - PerfLocks – Any explicit user space or kernel space perflocks to boost CPU frequency or the number of CPU cores at runtime
  - PowerHAL updates – Any system configuration updates (for various hints) that impact power/performance/thermal
  - Performance boosters – Boost performance mostly from input events
  - Detectors – Boost performance mostly on specific set of applications or patterns of behaviors
  - Static/dynamic changes on configurations (power/thermal vs performance)
    - CPU frequency governor parameters
    - MP-Decision parameters
    - Thermal engine parameters (dynamic)

Verification – Complete Thermal Sanity

- First verify if thermal engine is running as service
  - "ps | grep thermal-engine" will display the current instance of thermal engine. If not, the thermal engine needs to be started as service.
  - Try to kill the thermal engine by issuing "kill -9 pid_of_thermal_engine" and then check again with "ps | grep thermal-engine" to see whether thermal engine is automatically restarted.
- Thermal engine configuration
  - For older targets, there are two sources of default configurations, hardcoded embedded rules and default thermal engine configuration file, /etc/thermal-engine.conf.
  - For APQ8084 and later targets, only embedded rules exist.
  - By performing "thermal-engine -o" one can verify all the default configurations.
- Thermal engine + kernel emergency mitigation protects the system from any thermal threats (for MSM8974 and later chipsets only)
  - Place the DUT into the temperature chamber at 50°C.
  - Run highly stressful apps such as quad-dhrystone, Antutu, or StabilityApp for at least 5 min without a crash.
  - Kill thermal-engine and run for an additional 5 min.
  - Stop thermal-engine and run for an additional 5 min.
  - Verify no tsens_reset happens (by looking at reset reason if device reset).

Thermal Tuning Procedure

Thermal Tuning Procedure Overview

- This tuning procedure will identify a chipset temperature sensor (TSENS) reading that will correlate to whichever item below hits its thermal limit first based on incorporated algorithm (Monitor, SS, and PID):
  - Maximum chipset case temperature as defined in the device spec (typically 85°C)
  - Device skin hotspot (typically 45°C)
- Monitor algorithm
  - When the correlated TSENS temp exceeds the maximum case/skin temperature while running the tests, stop the test and edit the thermal-engine.conf file to reduce the “thresholds” and “threshold_clr” temperature values at steady state.
- Dynamic thermal algorithm
  - When the correlated TSENS temperature exceeds the maximum case/skin temperature while running the tests, stop the test and edit the thermal-engine.conf file to reduce the “set_point” and “set_point_clr” temperature values at steady state.
  - Generally speaking, DTM is ***strongly*** recommended over monitor for CPU and GPU mitigation because it greatly relieves tuning effort, and boost performance as well.

Monitor – Thermal Tuning Procedure

1. Place the DUT into the temperature chamber at 25°C.
2. Ensure that the thermal mitigation is enabled.
3. Read the thermocouple, the temperature value should be ~25°C since the ambient is at 25°C.
4. Turn on the DUT.
5. Connect the micro USB cable.
6. Open a command prompt on the PC and enter the case-sensitive command adb root.
7. Disable Wi-Fi and enable Airplane mode.
8. Go to Settings→Display settings and turn on the brightness to maximum.
9. In Display settings, set sleep mode/screen timeout to Never.
10. Open a command prompt and type “adb root”, “adb shell”, and look for “root@android”. Keep the USB cable plugged in.
11. Start TSENS and thermocouple logging simultaneously.
12. Start the Agilent Data Logger for thermocouple temperature logging.
13. Open another command prompt and type “adb shell”. Start TSENS logging app if available, otherwise, try to grep temperature information from thermal-engine logcat log (logcat –v time –s ThermalEngine).
14. Wait 1 min to allow everything to synchronize.

Monitor – Thermal Tuning Procedure (cont.)

15. Run Dhrystone on each CPU core (this heats up the device as fast as possible), e.g., for a 4 core device, run 4 instances of Dhrystone from adb command line.
16. Log thermocouple and TSENS temperatures until the chipset exceeds its maximum case temperature (typically 85°C) *or* until the skin hotspot temperature rises more than acceptable limits (typically 45°C) *or* the system crashes.
17. If the system crashes before maximum case or skin hotspot conditions are reached, then go back to step 15. However, run Dhrystone on one less core to reduce the temperature, e.g., run Dhrystone on 3 cores instead of 4.
18. Pick the TSENS that closely tracks the skin hotspot/case temperature and make sure that this sensor is not on the CPU (Krait).
19. Edit the default thermal-engine.conf file as follows:

[tsens_tz_sensorX]					(Temp sensor # on the Chipset Die)
Sampling	1000				(Temp sensor sampling rate in ms)
Thresholds	90000	95000	100000	120000	(Enable Temp in°mC)
Thresholds_clr	85000	90000	95000	115000	(Disable Temp in °mC)
Actions	cpu	cpu	cpu	shutdown	
Action_info	1512000	1296000	918000	5000	(CPU Clock Frequency in Hz)

20. If the skin hotspot temperature is way below the acceptable limits, increase all thresholds and threshold_clr values by 5°C and return to step 15. If the skin hotspot temperature exceeds the acceptable limits, decrease all thresholds and threshold_clr values by 5°C and return to step 15.

Monitor – Thermal Tuning Procedure (cont.)

21. Edit the default thermal-engine.conf file as follows:

    If temperature is low on the device skin, we need to increase all temperature thresholds by 5°C.

[tsens_tz_sensorX]					(Temp sensor # on the Chipset Die)
Sampling	1000				(Temp sensor sampling rate in ms)
Thresholds	**95000**	**100000**	**105000**	120000	(Enable Temp in °mC)
Thresholds_clr	**90000**	**95000**	**100000**	115000	(Disable Temp in °mC)
Actions	cpu	cpu	cpu	shutdown	
Action_info	1512000	1296000	918000	5000	(CPU Clock Frequency)

    If temperature is high on the device skin, we need to decrease all temperature thresholds by 5°C.

[tsens_tz_sensorX]					(Temp sensor # on the Chipset Die)
Sampling	1000				(Temp sensor sampling rate in ms)
Thresholds	**85000**	**90000**	**95000**	120000	(Enable Temp in °mC)
Thresholds_clr	**80000**	**85000**	**90000**	115000	(Disable Temp in °mC)
Actions	cpu	cpu	cpu	shutdown	
Action_info	1512000	1296000	918000	5000	(CPU Clock Frequency in Hz)

22. If the TSENS temperature no longer increases over time and the skin hotspot temperature limits are within acceptable limits, tuning is finished.

Monitor – thermal-engine.conf File Example

```
[tsens_tz_sensorX]
Sampling          1000     (Temp sensor sampling rate in ms)
Thresholds        75000   78000  81000  84000  87000  90000     (Enable Temp in °mC)
Thresholds_clr    72000   75000  78000  81000  84000  87000     (Disable Temp in °mC)
Actions           cpu     cpu    cpu    cpu    cpu    shutdown
Action_info       1296000 1188000 918000 756000 648000 5000     ( CPU Freq in Hz)
```

Increasing temperature decreases CPU clock rates

Monitor – thermal-engine.conf File Example (Customer Must Edit)

```
debug
sampling          5000

[pa_therm0]
sampling          1000
thresholds        70000 80000  90000
thresholds_clr    65000 75000  85000
actions           modem    modem    modem
action_info       1    2    3

[tsens_tz_sensor0]
sampling          1000
thresholds        65000    90000    93000    96000    99000    102000   105000
thresholds_clr    62000    87000    90000    93000    96000    99000    102000
actions           cpu      cpu      cpu      cpu      cpu      cpu      shutdown
action_info       1512000  1296000  1188000  918000   756000   648000   5000

[tsens_tz_sensor1]
sampling          1000
thresholds        75000
thresholds_clr    72000
actions           none
action_info       0
```

Modem mitigation based on PA thermister

CPU mitigation based on internal temperature sensors

Unused temperature sensor

Sample thermal-engine.conf File

```
[tsens_tz_sensor2]
sampling         1000
thresholds       75000
thresholds_clr   72000
actions          none
action_info      0

[tsens_tz_sensor3]
sampling         1000
thresholds       75000
thresholds_clr   72000
actions          none
action_info      0

[tsens_tz_sensor4]
sampling         1000
thresholds       75000
thresholds_clr   72000
actions          none
action_info      0
```


DTM – Thermal Tuning Procedure

1. Place the DUT into the temperature chamber at 25°C.
2. Ensure that the thermal mitigation is enabled.
3. Read the thermocouple, the temperature value should be ~25°C since the ambient is at 25°C.
4. Turn on the DUT.
5. Connect the micro USB cable.
6. Open a command prompt on the PC and enter the case-sensitive command adb root.
7. Disable Wi-Fi and enable Airplane mode.
8. Go to Settings→Display settings and turn on the brightness to maximum.
9. In Display settings, set sleep mode/screen timeout to Never.
10. Open a command prompt and type “adb root”, “adb shell”, and look for “root@android”. Keep the USB cable plugged in.
11. Start TSENS and thermocouple logging simultaneously.
12. Start the Agilent Data Logger for thermocouple temperature logging.
13. Open another command prompt and type“adb shell”. Start TSENS logging app if available. Otherwise, try to grep temperature information from thermal-engine logcat log (logcat –v time –s ThermalEngine).
14. Wait 1 min to allow everything to synchronize.

DTM – Thermal Tuning Procedure (cont.)

15. Run Dhrystone on each CPU core (this heats up the device as fast as possible), e.g., for a 4 core device, run 4 instances of Dhrystone from an adb command line.
16. Log thermocouple and TSENS temperatures until the chipset exceeds its maximum case temperature (typically 85°C) or until the skin hotspot temperature rises more than acceptable limits (typically 45°C) or the system crashes.
17. If the system crashes before maximum case or skin hotspot conditions are reached, then go back to step 15. However, run Dhrystone on one less core to reduce the temperature, e.g., run Dhrystone on 3 cores instead of 4.
18. Pick the TSENS that closely tracks the skin hotspot/case temperature and make sure that this sensor is not on the CPU (Krait).

DTM – Thermal Tuning Procedure (cont.)

19. Disable embedded rules if not needed.

```
[PID-CPU0]
disable 1
[PID-CPU1]
disable 1
[PID-CPU2]
disable 1
[PID-CPU3]
disable 1
[PID-POPMEM]

disable 1
```

20. Edit the default thermal-engine.conf file as follows:

[SS-CPU0]		
algo_type	ss	(algorithm type – SS)
Sensor	cpu0	(Sensor – cpu0 maps to tsens_tz_sensor5 for MSM8974 based on alias table)
Sampling	65	(65 ms sampling rate)
device	cpu	(mitigation device: for all CPUs)
set_point	90000	(mitigation target at 90°C and sampling starts once this threshold crosses over)
set_point_clr	55000	(sampling ends once temperature goes below this threshold, 55°C)

21. If the skin hotspot temperature is way below the acceptable limits, increase all set_point and set_point_clr values by 5°C and return to step 15. If the skin hotspot temperature exceeds the acceptable limits, decrease all set_point and set_point_clr values by 5°C and return to step 15.

DTM – Thermal Tuning Procedure (cont.)

22. Edit the default thermal-engine.conf file as follows:

If temperature is low on the device skin, we need to increase all temperature thresholds by 5°C.

[SS-CPU0]

algo_type	ss	(algorithm type – SS)
Sensor	cpu0	(Sensor – cpu0 maps to tsens_tz_sensor5 for MSM8974 based on alias table)
Sampling	65	(65 ms sampling rate)
device	cpu	(mitigation device: for all CPUs)
set_point	**95000**	(mitigation target at 95ºC and sampling starts once this threshold crosses over)
set_point_clr	**60000**	(sampling ends once temperature goes below this threshold, 60°C)

If temperature is high on the device skin, we need to decrease all temperature thresholds by 5°C.

[SS-CPU0]

algo_type	ss	(algorithm type – SS)
Sensor	cpu0	(Sensor – cpu0 maps to tsens_tz_sensor5 for MSM8974 based on alias table)
Sampling	65	(65 ms sampling rate)
device	cpu	(mitigation device: for all CPUs)
set_point	**85000**	(mitigation target at 85°C and sampling starts once this threshold crosses over)
set_point_clr	**50000**	(sampling ends once temperature goes below this threshold, 50°C)

23. If the TSENS temperature no longer increases over time and the skin hotspot temperature limits are within acceptable limits, tuning is finished.

Sample thermal-engine.conf File (DTM)

```
[PID-CPU0]
disable       1
[PID-CPU1]
disable       1
[PID-CPU2]
disable       1
[PID-CPU3]
disable       1
[PID-POPMEM]
disable       1

[SS-CPU0]
algo_type     ss
sensor        cpu0
sampling      65
device        cpu
set_point     90000
set_point_clr 55000

[SS-CPU1]
algo_type     ss
sensor        cpu1
sampling      65
device        cpu
set_point     90000
set_point_clr 55000
```

Embedded PID rules are disabled

DTM algorithm for CPU mitigation

```
[SS-CPU2]
algo_type ss
sensor        cpu2
sampling      65
device        cpu
set_point     90000
set_point_clr 55000

[SS-CPU3]
algo_type     ss
sensor        cpu3
sampling      65
device        cpu
set_point     90000
set_point_clr 55000

[SS-POPMEM]
algo_type     ss
sensor        pop_mem
sampling      65
device        cpu
set_point     80000
set_point_clr  50000
time_constant 16
```

Sensor Alias Table

- MSM8960
  - "tsens_tz_sensor0" = "cpu0"
  - "tsens_tz_sensor2" = "cpu1“
  - "tsens_tz_sensor3" = "pop_mem"
- MSM8930
  - "tsens_tz_sensor9" = "cpu0"
  - "tsens_tz_sensor6" = "cpu1"
  - "tsens_tz_sensor3" = "pop_mem"
- APQ8064
  - "tsens_tz_sensor7" = "cpu0"
  - "tsens_tz_sensor8" = "cpu1"
  - "tsens_tz_sensor9" = "cpu2"
  - "tsens_tz_sensor10" = "cpu3"
  - "tsens_tz_sensor6" = "pop_mem"
- MSM8974
  - "tsens_tz_sensor5" = "cpu0"
  - "tsens_tz_sensor6" = "cpu1"
  - "tsens_tz_sensor7" = "cpu2"
  - "tsens_tz_sensor8" = "cpu3“
  - "tsens_tz_sensor3" = "pop_mem"
- MSM8226
  - "tsens_tz_sensor5" = "cpu0-1"
  - "tsens_tz_sensor2" = "cpu2-3"
  - "tsens_tz_sensor3" = "pop_mem"
- MSM8610
  - "tsens_tz_sensor5" = "cpu0-1-2-3"
  - "tsens_tz_sensor0" = "pop_mem"

CPU Only Mitigation for GPU Intensive Program (Egypt)

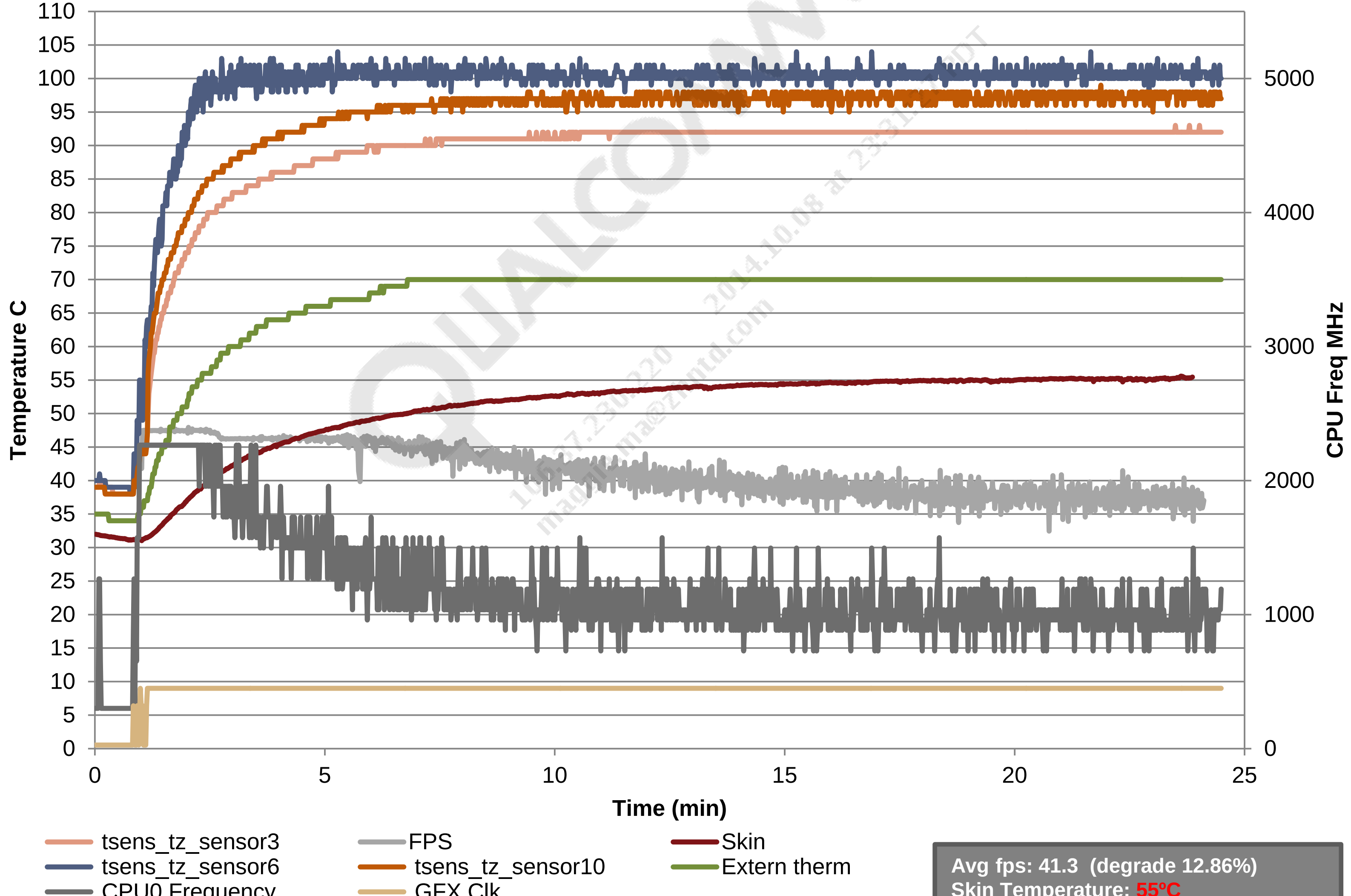
- No skin mitigation is defined
- Rules

```
[CPUx_MONITOR] (For CPU 0 through CPU3)
algo_type       monitor
sensor          cpu0
sampling        65              (65 ms sampling rate)
thresholds      120000          (shutdown at 120°C)
thresholds_clr  115000
actions         shutdown
action_info     70

[SS-CPUx]       (For CPU 0 through CPU3)
algo_type       ss              (algorithm type – SS)
sampling        65              (65 ms sampling rate)
sensor          cpu0
Device          cpu
set_point       95000           (target temperature of 95°C)
set_point_clr   55000
```

- Next graph displays thermal characteristics of MSM8974 for Egypt 2.5 HD benchmark program without mitigation for skin

MSM8974 Egypt 2.5 HD, Mitigation for CPU Temperature – Best Case Performance



Avg fps: 41.3 (degrade 12.86%)
Skin Temperature: 55ºC

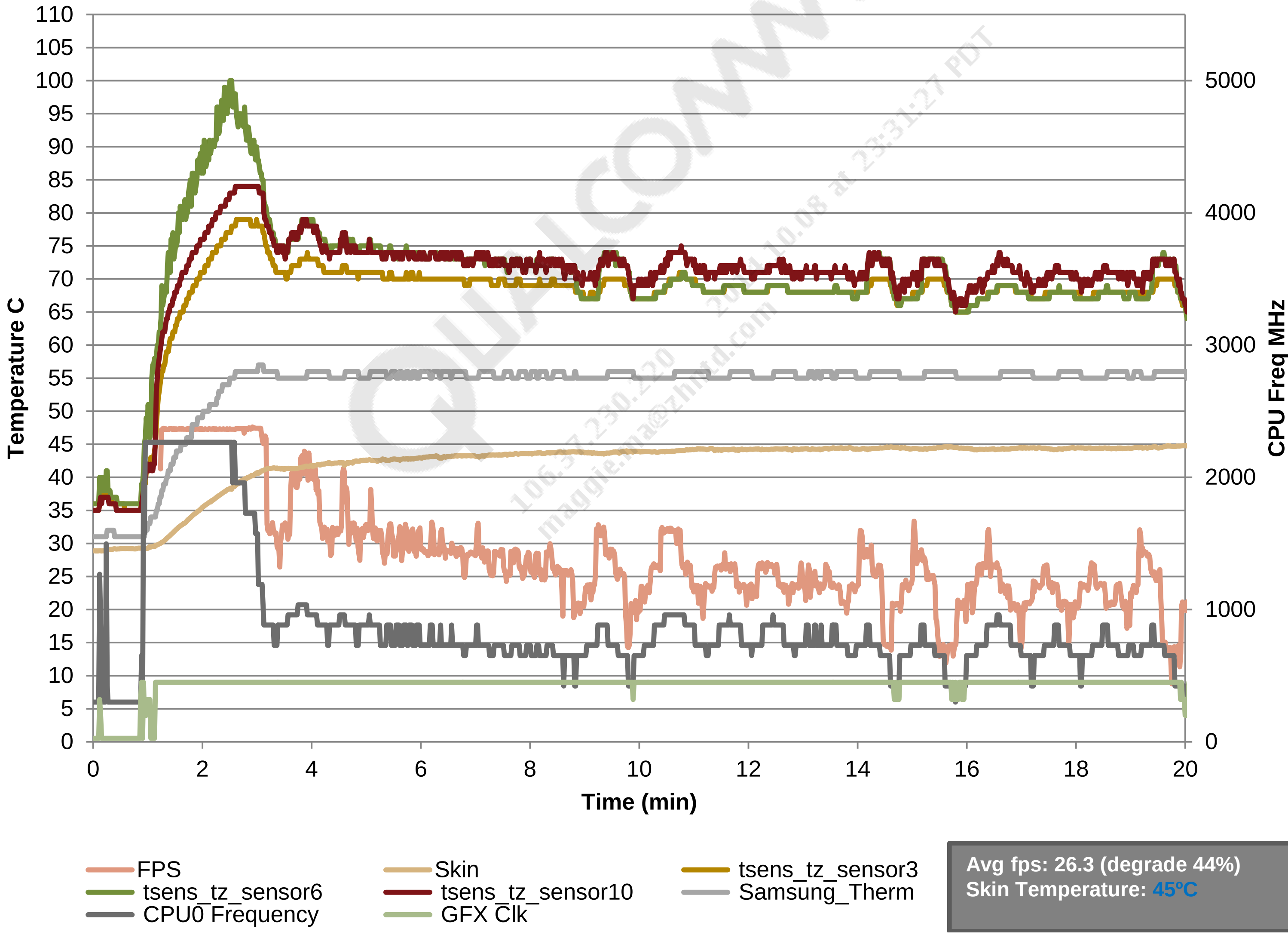
Additional Rules for Skin Control

- In this example, we have an external thermistor named skin
  - Steady state temperature delta is identified as 10ºC
- Additional rule

[SS-SKIN]		
algo_type	ss	(algorithm type – SS)
sampling	65	(65 ms sampling rate)
sensor	skin	(external thermistor on PCB)
device	cpu	(mitigation device – for all CPUs)
set_point	55000	(mitigation target at 55°C)
set_point_clr	45000	(sampling ends once temperature goes below this threshold)
time_constant	154	(154*60=10s of sampling if there is no change on sensor)

- Next graph displays thermal characteristics of MSM8974 for Egypt 2.5 HD benchmark program with CPU mitigation for skin

MSM8974 Egypt 2.5 HD, CPU Mitigation for Skin



Avg fps: 26.3 (degrade 44%)
Skin Temperature: 45ºC

Additional Rules for GPU Control

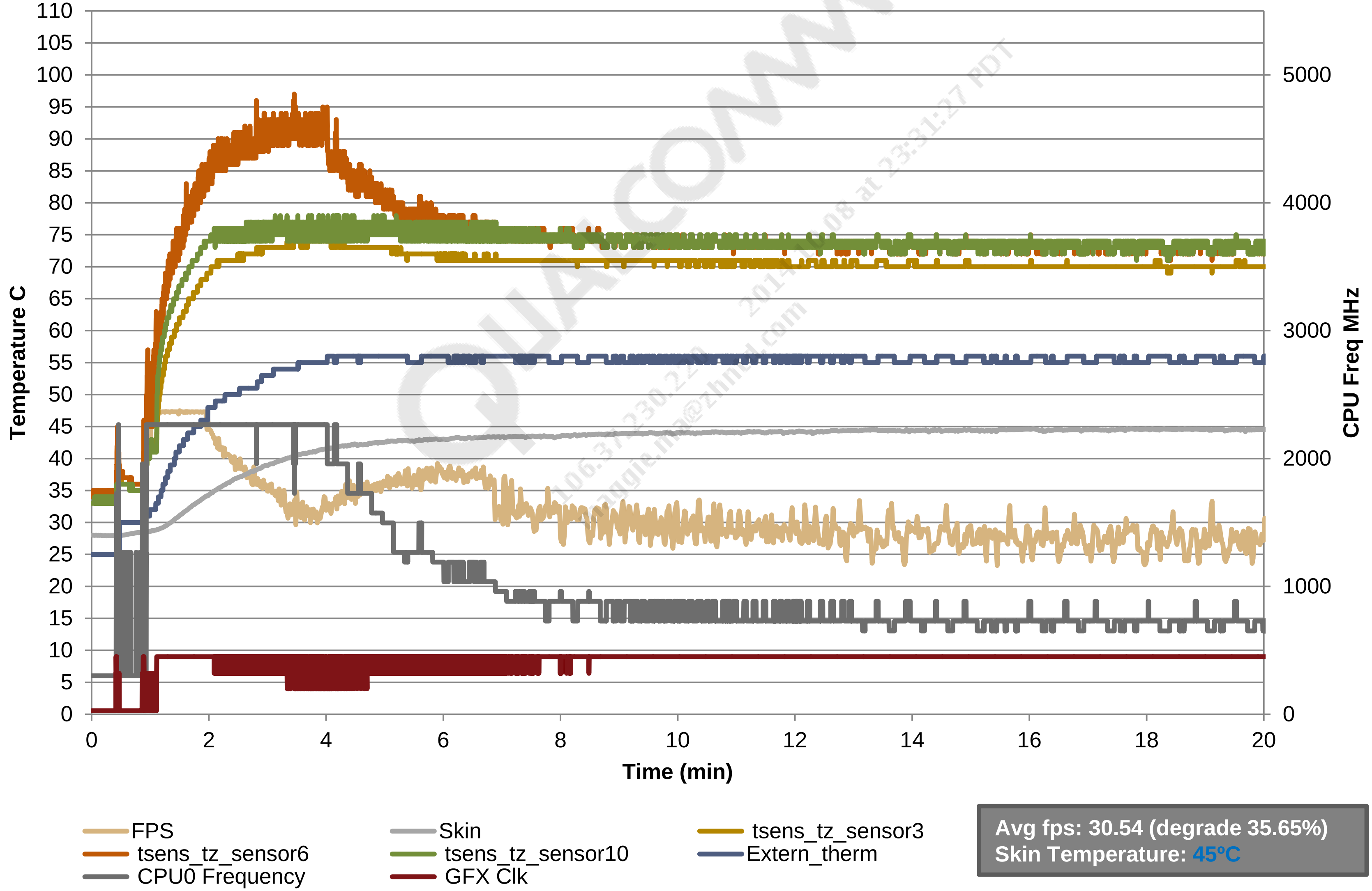
- GPU mitigation along with CPU mitigation can help boost the performance for GPU intensive programs
- Need to profile which combination can help the most
  - CPU only mitigation
  - GPU only mitigation
  - CPU+GPU mitigation

SS-GPU]

algo_type	ss	(Algorithm type – SS)
sampling	65	(65 ms sampling rate)
sensor	tsens_tz_sensor10	(Sensor – tsens_tz_sensor10 in MSM8974)
device	gpu	(Mitigation device – for GPU)
set_point	75000	(Mitigation target at 75°C)
set_point_clr	55000	(Sampling ends once temperature goes below this threshold)

- Next graph displays thermal characteristics of MSM8974 for Egypt 2.5 HD benchmark program with CPU+GPU mitigation for skin

MSM8974 Egypt 2.5 HD, CPU and GPU Mitigation for Skin



Avg fps: 30.54 (degrade 35.65%)
Skin Temperature: 45ºC

Purchasing Data Acquisition (DAQ)/Switch Unit

- Purchase your DAQ with your 20-channel multiplexers
  - DAQ – See [R1]
  - Free software download – See [R2]
- Under Supporting Documents, halfway down the page there is a link for Benchlink Data Logger 3 Getting Started Guide. This covers everything from the IO libraries to hardware and software.
  - Ignore instructions that deal with the buttons on the front. This is all controlled by the application on your PC/laptop.
  - The only thing you need to do with the front panel is press and hold the Power button the first time you power it up.
  - You do not need to ever power down this device.

Thermal Calibration for Speaker Protection

Thermal Calibration Procedure for Speaker Coil Protection

- Overview
  - The goal of thermal calibration for the speaker coil is to accurately estimate the temperature of the speaker coil from the available temperature sensors in the system.
  - This can be achieved through a three part process:
    I. Derive Equation to Convert Resistance to Temperature
    II. Determine Offset Value for Thermal Management Algorithm
    III. Program Offset into Device
  - This process is completed prefactory and should be redone anytime there is an electrical or mechanical design change to the device.
    - Required equipment
    - Thermal chamber
    - Multimeter with 4-wire setup (for accuracy)
    - DUT with speaker disconnected from drive circuitry and the coil wired out to the meter for resistance measurement. **Note:** DUT should be fully reassembled prior to testing.

Thermal Calibration Procedure for Speaker Coil Protection (cont.)

- Part I – Derive Equation to Convert Resistance to Temperature
  - Start by taking multiple resistance measurements manually, i.e., with multimeter, at different temperatures. These measurements can be used to derive an equation (described on next slide) that represents temperature as a function of resistance, by taking advantage of the linear relationship between resistance and temperature.

Preconditions

- DUT with speaker disconnected from drive circuitry and the coil wired out to the meter for resistance measurement. **Note:** DUT should be fully reassembled prior to testing.
- Device is powered off.

Procedure

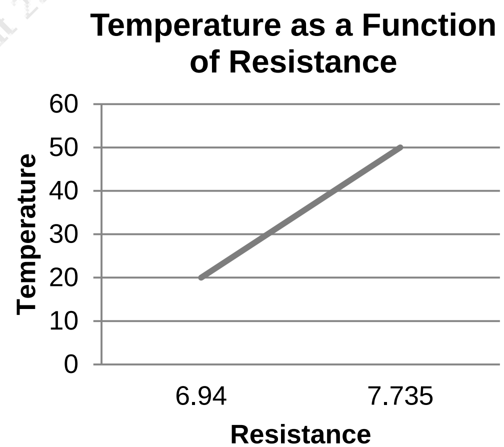
1. Set the thermal chamber to a known temperature, e.g., 20°C. The ambient temperature of the chamber should be monitored and verified by placing a thermocouple next to the device's speaker. Reminder, the phone should be powered off during these steps.
2. Place the phone in the chamber and allow to soak for at least 30 min, allowing the coil resistance to stabilize. Record coil resistance at 20°C. **Note:** Resistance variation should be less than 0.4% of nominal speaker resistance, e.g., for 8Ω, resistance variation should be < 0.03Ω, within 10 min.
3. Repeat steps 1 and 2 for at least one other temperature, e.g., for 50°C for greater accuracy, the steps can be repeated a third time, e.g., 0°C.
4. Resistance and temperature are assumed to have a linear relationship so now any two points can be used to find the device's function for temperature. This function can then be used to find the temperature of the speaker coil by simply plugging in the value of the resistance (example shown on next slide).

Thermal Calibration Procedure for Speaker Coil Protection (cont.)

- Part I – Derive Equation to Convert Resistance to Temperature (cont.)
  - Here is an example of finding temperature as a function of resistance based on two sample data points, using the equation for a line $y = mx + b$.
  - Example data

Sample	Temp – T	Resistance – R
1	20°C	6.94
2	50°C	7.735

Graphed →



Procedure

1. Find the slope of line $m = \frac{T1 - T2}{R1 - R2}$, per our example, $m = \frac{20 - 50}{6.94 - 7.735}$ = 37.73585
2. Find the y-intercept $b = y - mx$, per our example, $b = 20\ - 37.73585 * 6.94 =$ -241.887
3. Use the equation for a line to find the speaker coil temperature based on resistance $y = mx + b, where\ y = temp, and\ x = resistance,$ per our example, $y = 37.73585 * x - 241.887$.

Note: Use linear regression to approximate a temperature function based on more than two data samples.

Thermal Calibration Procedure for Speaker Coil Protection (cont.)

- Part II – Determine Offset Value for Thermal Management Algorithm
  - Now that we have an equation to calculate temperature, we can use it to help us determine the appropriate offset for the device. The following steps should be done for at least three different temperatures and with the device running as many initial power-on scenarios as the manufacturer wishes. The most common temperatures, environments, and scenarios are the most important.

Preconditions

- DUT with speaker disconnected from drive circuitry and the coil wired out to the meter for resistance measurement. **Note:** DUT should be fully reassembled prior to testing (same as Part I).
- Device software is installed.
- Device is powered on.

Procedure

1. Check for the file /data/misc/audio/audio.cal on the device. If this file exists, calibration has already happened. Remove the file and reboot the phone. Otherwise, proceed to step 2.
2. Connect USB debug command prompt to dump logs. Start logging with command – adb logcat –s ThermalEngine | grep –i speaker.
3. In order to obtain the necessary data for calibration, you need to wait until the log displays “min” temp (see logcat example below). This will take 30 min or longer. The logs will show a long sample cnt. When this count reaches 10, the speaker will calibrate and the logs will display the “min” temp (**Note:** We are NOT using SpeakerCal temp because it has the default offset factored in). The moment this log is shown, measure the resistance of the speaker coil (using multimeter) and hence calculate speaker temperature using the equation that was derived in Part I. The difference between the logged “min” temp and calculated temp is the offset; e.g., if the measurement from the 4-wire multimeter results in 27°C, the offset using the logcat example below would be 27 to 32 = -5°C.

Thermal Calibration Procedure for Speaker Coil Protection (cont.)

- Part II – Determine Offset Value for Thermal Management Algorithm

  Procedure (cont.)

  4. To verify calibration success, check for the existence of the file /data/misc/audio/audio.cal.
  5. Prepare the next temperature or scenario then remove the file /data/misc/audio/audio.cal and reboot the phone to start the next thermal calibration (go to step 2).

  - After collecting offset data for common ambient temperatures and scenario, an average of the offsets can be calculated and programmed into the phone.

```
01-10 04:47:19.159 E/ThermalEngine(  226): set_and_wait_alarm: Alarm Recieved 30000
01-10 04:47:19.159 E/ThermalEngine(  226): speaker_cal_algo: reading pm8941_tz 33168
mC
01-10 04:47:19.159 E/ThermalEngine(  226): speaker_cal_algo: reading[0] 33000 mC
01-10 04:47:19.159 E/ThermalEngine(  226): speaker_cal_algo: reading[1] 32000 mC
01-10 04:47:19.159 E/ThermalEngine(  226): speaker_cal_algo: reading[2] 33000 mC
01-10 04:47:19.159 E/ThermalEngine(  226): speaker_cal_algo: reading[3] 32000 mC
01-10 04:47:19.159 E/ThermalEngine(  226): speaker_cal_algo: reading[4] 32000 mC
01-10 04:47:19.159 E/ThermalEngine(  226): speaker_cal_algo: reading[5] 33000 mC
01-10 04:47:19.159 E/ThermalEngine(  226): speaker_cal_algo: reading[6] 33000 mC
01-10 04:47:19.159 E/ThermalEngine(  226): speaker_cal_algo: reading[7] 33000 mC
01-10 04:47:19.159 E/ThermalEngine(  226): speaker_cal_algo: min 32000 mC, max 33000
mC
01-10 04:47:19.159 I/ThermalEngine(  226): speaker_cal_algo: Speaker Cal temp 28C
01-10 04:47:19.159 E/ThermalEngine(  226): speaker_cal_algo: Success notifying spkr
clients
```

Thermal Calibration Procedure for Speaker Coil Protection (cont.)

- Part III – Program Offset into Device
  - Now our averaged offset can be used for the offset field of the thermal-engine.conf file, which is found at /vendor/qcom/proprietary/thermal-engine/.
  - The speaker coil calibration instance is identified by the label SPEAKER-CAL (example below) in the thermal-engine.conf file.

```
[SPEAKER-CAL]
sampling     30000 30000 10 1800000
sensor       pm8941_tz
sensors      tsens_tz_sensor1 tsens_tz_sensor2 tsens_tz_sensor3
             tsens_tz_sensor4 tsens_tz_sensor7 tsens_tz_sensor8
             tsens_tz_sensor9 tsens_tz_sensor10
temp_range   6000 10000 2000
max_temp     45000
offset       -4000
```

  - If there is no preexisting instance of SPEAKER-CAL in the thermal-engine.conf file, the above example can be added and the offset value updated based on your results from Part II.
  - **Note:** The sensors line needs to be one contiguous line without any returns in the configuration file.
  - For the fields sampling, sensor, sensors, temp_range, and max_temp, see [R3].

Thermal Lab Setup

Thermal Lab Setup

Assembly/Disassembly/Rework Bench						
Equipment/tool	**Description**	**Manufacturer**	**Manufacturer model/part #**	**Vendor**	**Vendor part #**	**QTI contact**
Technician toolbox	**Total of 36 tools included**	SMS	1001-Q	Solder Master Supply	1001-Q	Test Equipment
Adjustable wrench	6" adjustable wrench with red vinyl grip, 15/16" capacity	Crescent	AC16C	Stanley Supply & Services	402-051	Test Equipment
Adjustable wrench	4" adjustable wrench	Iron Bull	NA	Solder Master Supply	NA	Test Equipment
Plier/cutter	4-1/2" transverse end cutter pliers	Xcelite	EC54-J	Stanley Supply & Services	190-142	Test Equipment
Plier	Electronic pliers, round Jaw 4.5"	Xcelite	RN54	Stanley Supply & Services	114-809	Test Equipment
Plier	Combination "slip joint" plier 6"	Crescent	H26C	Stanley Supply & Services	403-684	Test Equipment
Plier	Groove joint plier 7"	Crescent	R27C	Stanley Supply & Services	114-808	Test Equipment
Wire stripper	T Stripper, 16 to 26 AWG, stranded wire	Ideal	45-121	Stanley Supply & Services	118-568	Test Equipment
Cutters	Angled cutter	Erem	2475E	Stanley Supply & Services	447-800	Test Equipment
Pick	Angle stainless steel probe, 5-1/2" long	Menda	35617	Stanley Supply & Services	151-166	Test Equipment
Forceps	Straight nose 5.5" seizer	Xcelite	42HV	Stanley Supply & Services	151-017	Test Equipment
Tape measure	1.5" x 10' measuring tape	Lufkin	L610	Solder Master Supply	NA	Test Equipment
Screwdriver	Regular Phillips screwdriver, #1 tip, 3" blade, 6-5/8" overall	Xcelite	X101	Stanley Supply & Services	115-589	Test Equipment
Screwdriver	Regular Phillips screwdriver, #2 tip, 4" blade, 8-1/8" overall	Xcelite	X102	Stanley Supply & Services	115-591	Test Equipment
Screwdriver	Slotted screwdriver, regular style, 1/8" x 2"	Xcelite	R182	Stanley Supply & Services	115-525	Test Equipment
Screwdriver	Regular Phillips screwdriver, #0 tip, 2" blade, 4-1/2" overall	Xcelite	X100	Stanley Supply & Services	115-588	Test Equipment
Screwdriver	Regular slotted, 1/4" tip, 4" blade, 8-1/8" overall	Xcelite	R144	Stanley Supply & Services	115-520	Test Equipment
Screwdriver	Regular slotted, 3/16" tip, 6" blade, 9 1/2" overall	Xcelite	R3166	Stanley Supply & Services	115-533	Test Equipment
Scissors	4 1/8" embroidery scissors	Cozic	KHS-105	Solder Master Supply	NA	Test Equipment
Tweezer	Tweezer, style 00, 4-3/4" long	CHP	00-SA	Solder Master Supply	NA	Test Equipment
Tweezer	Tweezer, style AA	CHP	AA-SA	Solder Master Supply	NA	Test Equipment

Thermal Lab Setup (cont.)

Assembly/Disassembly/Rework Bench (cont.)						
Equipment/tool	**Description**	**Manufacturer**	**Manufacturer model/part #**	**Vendor**	**Vendor part #**	**QTI contact**
Technician toolbox	**Total of 36 tools included**	SMS	1001-Q	Solder Master Supply	1001-Q	Test Equipment
Wire unwrapping tool	24-32 AWG/counter clock wise direction	JDV Products	HU93	Solder Master Supply	NA	Test Equipment
PinVise	Double-end PinVise	Euro Tool	PIN219.00	Stanley Supply & Services	125-362	Test Equipment
Drill set	61-80 - .0390-.0135 drill set	Euro Tool	DRL-240.00	Solder Master Supply	N/A	Test Equipment
Chip puller	Static-dissipative PLCC extractor	C.K.	2371	Stanley Supply & Services	126-453	Test Equipment
Cutters	Slim tapered head diagonal cutter	Swanstrom Tools	420-Jensen	Stanley Supply & Services	419-318	Test Equipment
Cutters	Miniature diagonal semi flush electronic cutter, round nose	Xcelite	MS54	Stanley Supply & Services	115-074	Test Equipment
Wire stripper	No Nik wire stripper 32 AWG	No Nik	NN012	Stanley Supply & Services	4-303	Test Equipment
Desoldering pump	Static-free desoldering pump with aluminum barrel	Edsyn	SS350	Stanley Supply & Services	114-412	Test Equipment
Screwdriver set	6-pc miniature screwdriver set	Euro Tool	SCR-900.00	Solder Master Supply	NA	Test Equipment
Midget wrench set	10-pc midget combination wrench set (5/32-7/16")	Armstrong	25-600	Solder Master Supply	NA	Test Equipment
Precision knife	Precision knife and 5 blades	X-Acto	X3001	Stanley Supply & Services	119-336	Test Equipment
Steel ruler	6" precision rule with conversions (standard/metric/english)	Kristeel	401 A 5	Solder Master Supply	NA	Test Equipment
Needle file set	12-pc mini file set	Euro Tool	FIL-990.00	Stanley Supply & Services	401-442	Test Equipment
Long nose locking pliers	6" long nose locking pliers with wire cutter	Crescent	C6NV	Stanley Supply & Services	424-525	Test Equipment
Hex wrench set	L-wrench hex set 12-pc 050-5/16	Bondhus	12136	Stanley Supply & Services	174-435	Test Equipment
Needle nose pliers	Electronic pliers, long nose, serrated	Xcelite	LN55	Stanley Supply & Services	114-781	Test Equipment

Thermal Lab Setup (cont.)

Equipment/tool	Description	Manufacturer	Manufacturer model/part #	Vendor	Vendor part #	QTI contact
Tools (not included with toolbox)						
Miniature torx set	6-piece miniature torx screwdriver set	Wiha	26790	Stanley Supply & Services	115-218	Test Equipment
Pen vac	Pen vac kit with 4 tips	Excelta	PV-HV	Stanley Supply & Services	435-541	ESOS
Cutting mat with scale	X-Acto 18"x24" self healing cutting mat with 1" scale grid	X-Acto	X7762	Stanley Supply & Services	403-392	ESOS
Thermal test equipment						
Data module	20-channel multiplexer (2/4-wire) module for 34970A/34972A	Agilent	34901A	QTI		Test Equipment
Data logger	Data cquisition/data logger switch unit	Agilent	34970A	QTI		Test Equipment
GPIB PCI card	Interface card, NI PCI-GPIB NI-488.2 WIN 7/VISTA/XP/2000 ROHS	National Instruments		ESOS	—	ESOS
GPIB 2M cable	Cable, shielded IEEE-488 (GPIB/HPIB) metal hood 2M	NA		ESOS	—	ESOS
Consumables and materials						
Pana vise 201 JR.	Vise head rotates a full 360° and pivots 210°	PanaVise	201	Stanley Supply & Services	400-231	Test Equipment
Thermocouples	36 gauge K-type 6' thermocouples	Omega	5TC-TT-K-36-72	Test Equipment Supply Supply WT-371		ESOS
Swabs	6" cotton tipped applicators (Qty 100)	—	—	Test Equipment Supply Supply WT-371	NA	Test Equipment
Epoxy adhesive	50/50 epoxy/hardener (prepackaged) adhesive	AngstromBond	AB9226	Test Equipment Supply Supply WT-371	NA	Test Equipment
Instant adhesive	Cyanoacrylate (Loctite 444)	Loctite	12292	Test Equipment Supply Supply WT-371	NA	Test Equipment
Instant adhesive accelerator	Tak-pak accelerator 7452 (used with Loctite 444)	Loctite	18490	Test Equipment Supply Supply WT-371	NA	Test Equipment
Kapton tape	Kapton tape 1/2"	3M	5419	Test Equipment Supply Supply WT-371	NA	Test Equipment
Kapton tape	Kapton tape 1/4"	3M	5419	Test Equipment Supply Supply WT-371	NA	Test Equipment
Kimwipes	Lint-free cleaning wipes 4.4" x 8.4" (box contents 280 wipes)	Kimberly-Clark	NA	Test Equipment Supply Supply WT-371	NA	Test Equipment
Cleaning brushes	For cleaning at the PCB/PCA level (custom cut by KG)	NA	NA	Test Equipment Supply Supply WT-371	NA	Test Equipment
Wooden applicators	For applying liquid adhesives or support wire while adhesive cures	NA	NA	Test Equipment Supply Supply WT-371	NA	Test Equipment
Replacement x-Acto blades	Replacement X-Acto blades 100/pkg	X-Acto	X611	Stanley Supply & Services	119-362	Test Equipment
DMM	True-rms industrial logging multimeter with trendcapture	Fluke	Fluke 289	Stanley Supply & Services	444-379	Test Equipment

Benchmark Setup and Run Instructions

- glBENCHMARK 2.5 EGYPT HD (download from Google Play using the device)
  1. Open the application and select Performance Tests.
  2. Run “adb shell” and then “setprop persist.debug.glbench.time 9000” to freeze a frame (it will rerender in a continuous loop).
  3. Check the box by the first Egypt HD test (it will say ETC1 underneath it) and click **Start**.
- AnTuTu 3.0.1 or later (download from Google Play using the device)
  1. Open the application.
  2. Select **Start Test**.
  3. Select only CPU tests (no 2D/3D Graphics). Start the test.
  4. After the test completes, log the score and immediately start the test again.
  5. Repeat test 5x (6 runs total).

Benchmark Setup and Run Instructions (cont.)

- DHRYSTONE or similar (contact QTI for questions)
  1. Type “adb shell”, then type “/data/dhrystone.sh &” for four times for quad-dhrystone use case. This will run Dhrystone a total of four times.
  2. Close the chamber door and observe thermocouple temperatures via Data Logger on your PC.
- The TSENS temperature can be observed while under test
  1. Type “adb shell”, then type “cat /sys/devices/virtual/thermal/thermal_zone<tsens number>/mode”.
     - Should display Enabled
     - “cat /sys/devices/virtual/thermal/thermal_zone<tsens number>/temp” will display temperature
  2. At completion of test, click **Play on Agilent Data Logger** to stop logging.

References

Ref.	Document	
Qualcomm Technologies		
Q1	*Application Note: Software Glossary for Customers*	CL93-V3077-1
Q2	*Thermal Design Checklist*	80-VU794-21
Q3	*Design For Thermal: Key Requirements Why What Where When*	80-VU794-24
Q4	*Thermal Management of MSM8660/MSM8260/APQ8060 Devices*	80-VU872-16
Q5	*Thermal Protection Algorithm Overview*	80-VT344-1
Q6	*Application Note: MDM8200 Thermal Protection Algorithm*	80-VJ372-14
Q7	*Application Note: MDM9600 Thermal Protection Algorithm Details*	80-VP146-15
Q8	*Application Note: MDM9200 Thermal Protection Algorithm Details*	80-VP145-15
Q9	*Application Note: MDM8220 Thermal Protection Algorithm Details*	80-VP144-15
Q10	*MSM8960 Thermal Mitigation Algorithm*	80-N8633-1
Q11	*MDM9x15 Thermal Mitigation Algorithm*	80-N8633-2
Q12	*APQ8064+MDM9615 Thermal Management Algorithm*	80-N8633-3
Q13	*MSM8974 Thermal Management Algorithm*	80-N8633-6

References (cont.)

Ref.	Document	
References		
R1	*DAQ*	http://www.home.agilent.com/en/pd-1756491-pn-34972A/lxi-data-acquisition-data-logger-switch-unit?cc=US&lc=eng
R2	*Free Software*	http://www.home.agilent.com/agilent/software.jspx?cc=US&lc=eng&ckey=778242&nid=-33257.922596&id=778242
R3	*Agilent Data Logger 3 Getting Started Guide*	http://www.home.agilent.com/agilent/software.jspx?id=778242&cc=US&lc=eng

Questions?

https://support.cdmatech.com