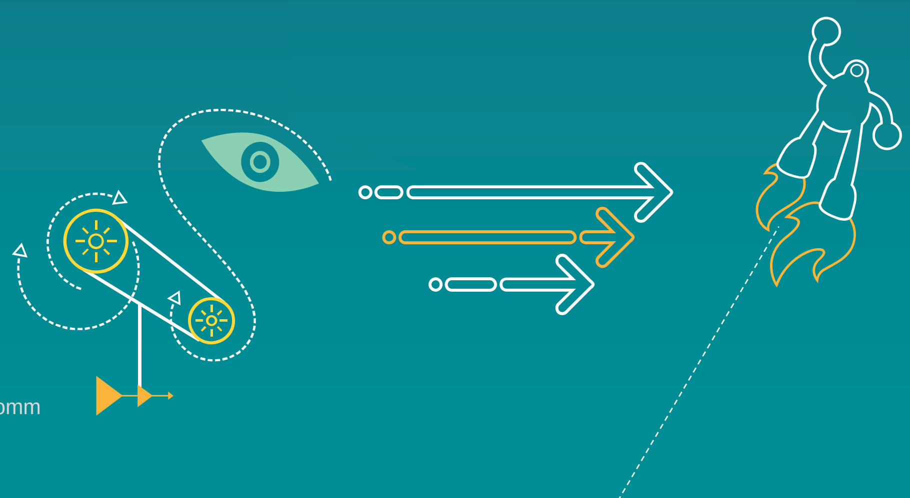
Application Note

Skin Temperature Measurement Procedure Using IR Camera

Qualcomm Technologies, Inc.



80-VU794-15 Rev. B

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

Revision History

Revision	Date	Description
A	January 2014	Initial release
B	July 2014	Slide 12: Added a picture for test fixture. Slide 13: Added a picture for thermal coupler location. Slide 14: Added for IR camera calibration. Slide 15 and 16: Added for surface emissivity setting example. Slide 20: Added some verbal change to explain the condition of identical. Added Appendix A for surface reflection removal. Added Appendix B for thermal sensor and standards.

Contents

1 Introduction 6

2 Preparation – IR Camera Selection and Test Setup 8

3 Before Test – IR Camera Calibration 12

4 Test Procedure 18

5 Comparing Skin Temperatures of Two Phones 20

6 Appendix A – Surface Reflection Removal 22

7 Appendix B – Notes on Thermal Sensors and Standards 29

Section 1

Introduction

Introduction

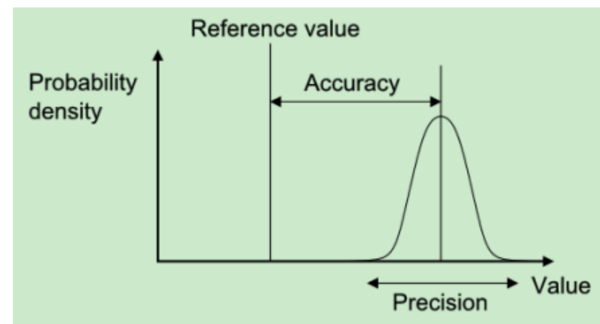
Scope

- This document is for engineers using an infrared (IR) camera for testing mobile phone skin temperatures.

Important

- IR cameras have significant accuracy and precision limitations*.
  - The accuracy of an IR camera is strongly influenced by the emissivity setting.
    - As the emissivity setting varies from 0 to 1, an IR camera measurement on unfinished aluminum can vary by up to 100°C!
  - A careful calibration of the IR camera for each surface to be tested is required.
    - Without a detailed calibration, measurements on IC packages and phones/tablets can easily be inaccurate by 5-10°C, and even relative trends (phone-to-phone) may not be valid. Calibrations are critical.

*** Note:** *Accuracy* is how close you are to a true or accepted value, while *precision* is how close data points are to each other, or how reproducible an experiment is.



Section 2

Preparation – IR Camera Selection and Test Setup

Preparation – IR Camera Selection and Test Setup (1 of 3)

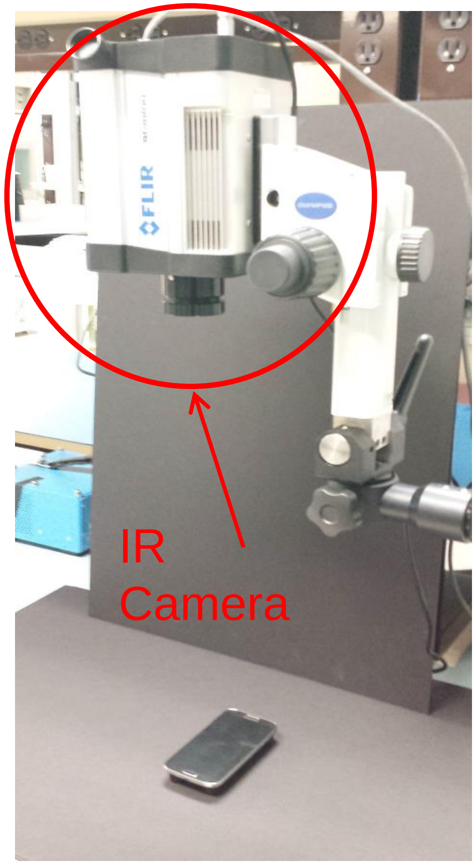
1. Select an IR camera that has an emissivity-setting as an input.
   - For example, one choice is a FLIR SC8000 HS - series IR camera.
2. Mount the IR camera on a stable tripod to reduce the variability of measurements.
3. Place the phone under test (that has been powered off and has cooled to room temperature) on a fixed horizontal surface.
4. Aim the camera straight down (along a vertical plane) at the phone. Tilt the phone from horizontal until the reflection spot completely disappears in the IR image. This tilt reduces camera self-reflection effect. (See Slide 10 for setup, and Appendix A for self-reflection examples)
   - Turn on the phone and perform initial test to determine where the phone's relative "hot spot" is located.
   - Ensure the IR camera is aimed directly at this location.
   - The phone must then be powered **off**.
5. Place four ambient temperature sensors between 10" and 20" away from the phone under test as described below. Ambient temperature measurement is a necessary baseline reference.
   - For the temperature sensors, it is best to use RTDs; otherwise Type-T thermocouples are acceptable. See Appendix B for recommended temperature sensors.
   - Do not place the temperature sensors above the phone, since hot air rises. The recommended way is to attach them to the inside walls (one sensor on each wall) of the enclosure used in the measurement. See Slide 10 for the enclosure setup.
   - Do not block line of sight between the IR camera and the phone under test with the temperature sensors.

Preparation – IR Camera Selection and Test Setup (2 of 3)

6. Verify that the phone under test is fairly cool (near ambient temperature). If not, leave the phone unpowered and wait until it is cool to the touch.
7. Place a solid cover to physically shield the test setup (phone and IR camera) from wind, air conditioning vent flow, and stray IR light.
   - Use a cardboard box that has been painted a dull (not shiny), matte, or flat black color (on both the inside and outside).
   - Place this cardboard box over the top of the phone and the IR camera setup, so that air flow is prevented and reflections from the room cannot enter the measurement area of the test setup.
   - See next slide for enclosure setup.

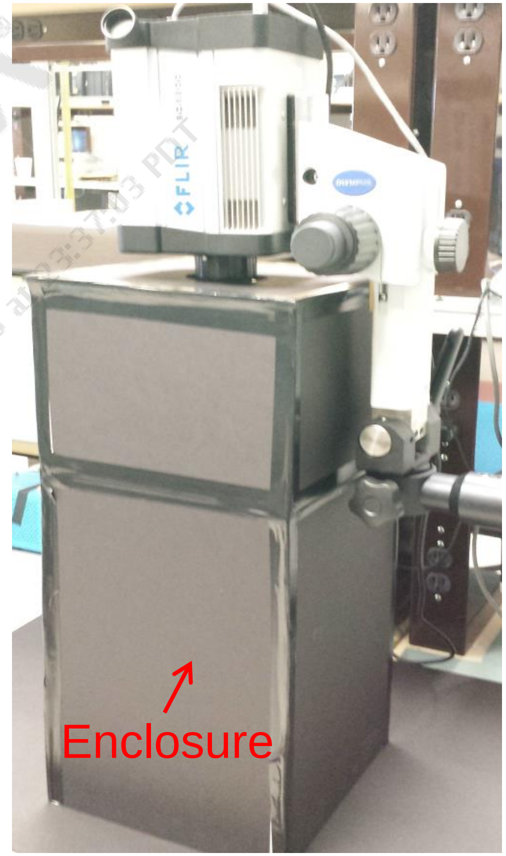
Recommended enclosure material: Foamboard 20 × 30

Preparation – IR Camera Selection and Test Setup (3 of 3)



Test setup without enclosure

Tilt angle (15 degree for example)



Test setup with enclosure

Notes:

- A test enclosure can be made from cardboard or paper-based foam core. The recommended width and depth (X,Y) should be approximately 4½ times of the phone being tested. However, the enclosure height will vary with IR camera lens capability, and the focal length between the tested phone and the IR camera.
- The 15 degree of tilt orientation is just an example here; the tilt angle depends on the distance between the device and IR camera, the IR camera characters, the lighting conditions, the surface, etc.

Section 3

Before Test – IR Camera Calibration

Before Test – IR Camera Calibration (1 of 3)

1. Wait for at least 20 minutes to ensure that all pieces equilibrate in temperature
   - Allow time for thermocouples and phone to cool down (after being touched) and for all of the pieces under the cover to exchange heat and reach the same ambient temperature

Before Test – IR Camera Calibration (2 of 3)

2. Since the surface emissivity of LCD and back cover is unknown, three T-type thermocouples are mounted at low, medium, and high-temperature zones at LCD and back cover. The recorded thermocouple readings will be used as the reference temperature to calibrate the emissivity of the LCD surface and back cover surface.

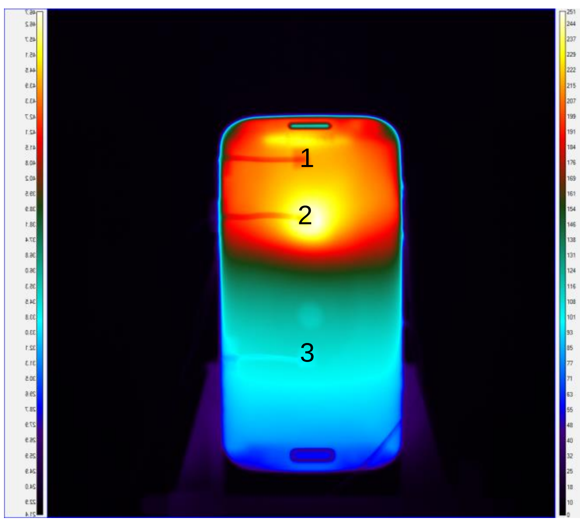
LCD
(Thermocouple location)

Back cover
(Thermocouple location)

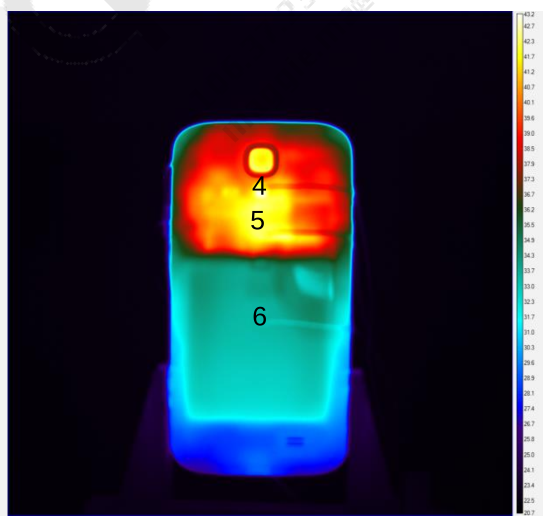
Before Test – IR Camera Calibration (3 of 3)

3. Turn on the phone at idle state and wait for 30 minutes until reach steady-state surface temperature. Adjust the surface emissivity setting of the IR camera until the temperature difference between thermocouple reading and IR camera reading is less than 1.0°C. The determined surface emissivity will be the emissivity of the LCD surface and back cover surface.
4. (Optional) Turn on the phone and run CPU intensive use case (such as Dhrystone), wait for 30 minutes until reach steady-state surface temperature. Then adjust the surface emissivity setting of the IR camera until the temperature difference between thermocouple reading and IR camera reading is less than 1.5°C. The determined surface emissivity will be the emissivity of the LCD surface and back cover surface.

LCD
(Thermal imaging)



Back cover
(Thermal imaging)



Phone at idle state

LCD		Backcover	
Surface Emissivity=0.92		**Surface Emissivity=0.92**	
IR(C)	TC(C)	IR(C)	TC(C)
24.4	24.4	23.1	23.1
23.4	23.1	22.8	22.9
22.9	22.8	22.6	22.8

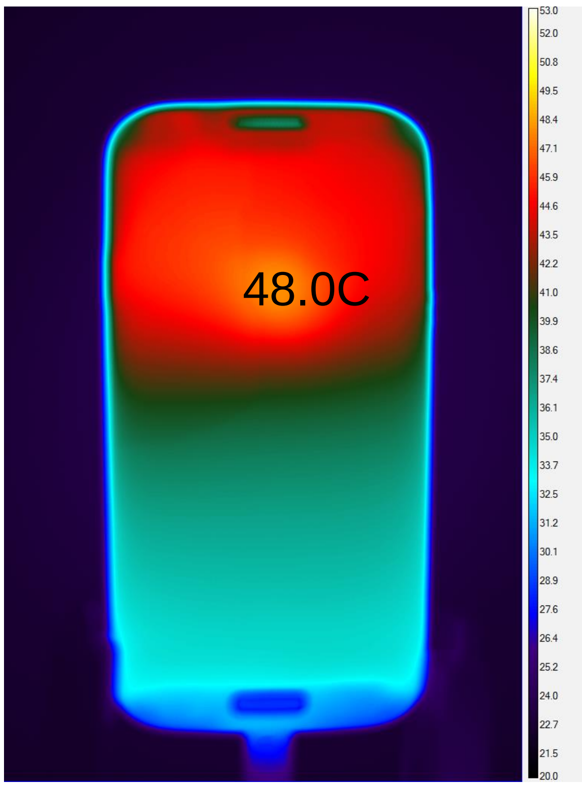
Phone with Quad-Dhrystone

LCD		Backcover	
Surface Emissivity=0.92		**Surface Emissivity=0.92**	
IR(C)	TC(C)	IR(C)	TC(C)
48.6	47.2	44.5	43.7
38.1	37.5	36.2	36.4
34.7	34.3	34.5	35.1

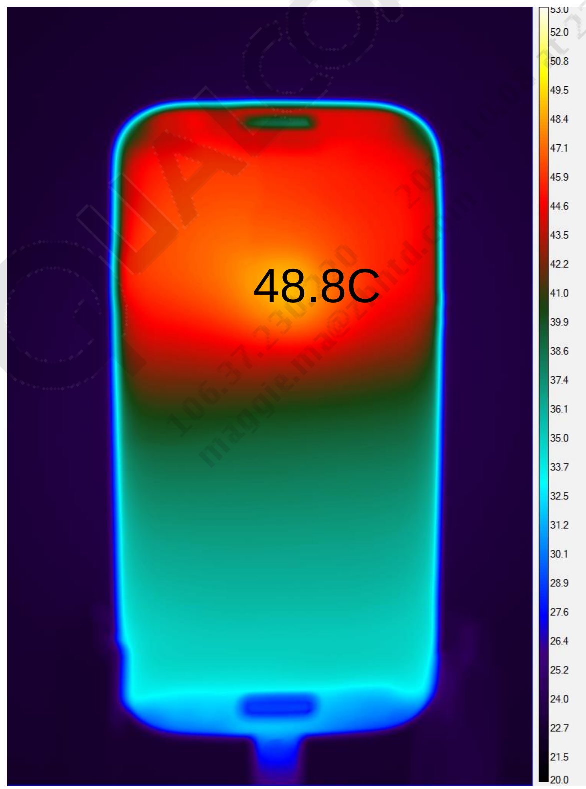
IR Camera Calibration – Surface Emissivity Setting Example (1 of 2)

- Incorrect surface emissivity would result in measurement errors. The following examples show how the surface emissivity of LCD can affect surface temperature of a real phone with Quad-Dhrystone.

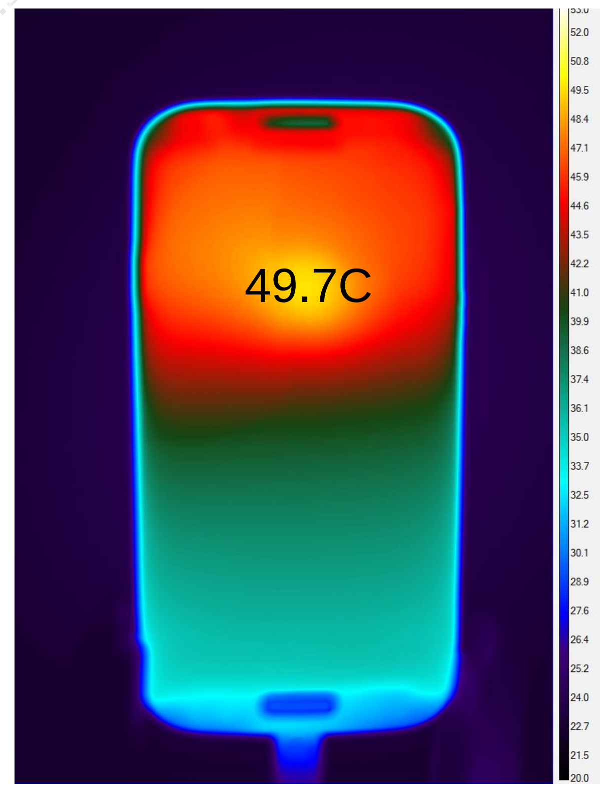
Surface emissivity = 1.00



Surface emissivity = 0.96



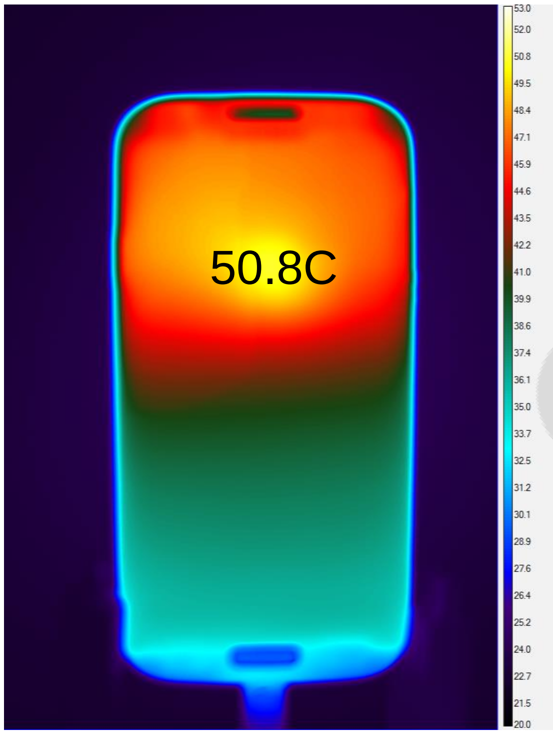
Surface emissivity = 0.92



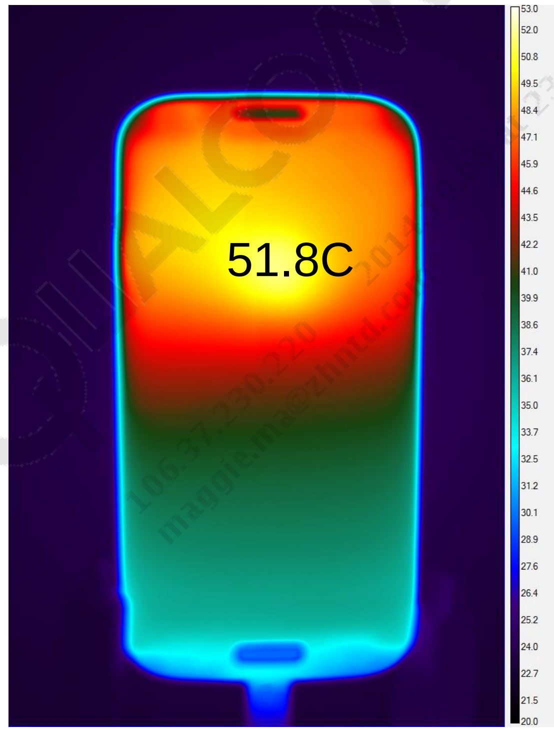
Sec. 3

IR Camera Calibration – Surface Emissivity Setting Example (2 of 2)

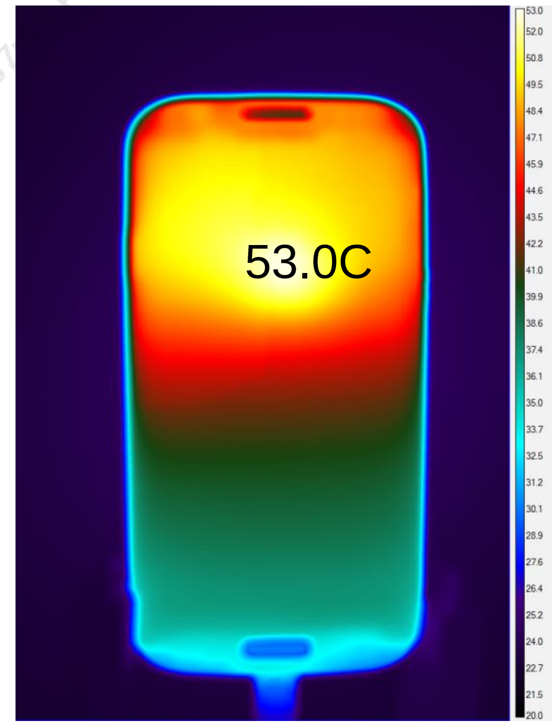
Surface emissivity = 0.88



Surface emissivity = 0.84



Surface emissivity = 0.80



Surface emissivity	1.00	0.96	0.92	0.88	0.84	0.80
Hotspot temperature (C)	48.0	48.8	49.7	50.8	51.8	53.0

Section 4

Test Procedure

Test Procedure

1. Power on the phone (make sure not to move it).
2. Run the application of interest
3. Using the IR camera, take the average temperature, over an area (25 × 25 mm for example), that corresponds with the phone's surface "hot spot."
4. Record the results.

Note: Following the preparations/setup/procedures described above should greatly improve the accuracy of the IR camera measurement results. However, achieving IR camera specifications (±2°C for example) for temperature accuracy is not guaranteed, even though that figure is sometimes mentioned by camera manufacturers, for ideal calibration and measurement conditions.

Later versions of this application note will include a description of gauge repeatability and reproducibility (GR&R). This is a methodology that quantifies the precision of the measurement system. Do not blindly trust results from the IR camera. *Use the GR&R method to learn the amount of uncertainty due to variations in the measurement system, to aid with data interpretation*.

Section 5

Comparing Skin Temperatures of Two Phones

Comparing Skin Temperatures of Two Phones

Sometimes it is needed to compare the skin temperature of two phones, however, only expect identical thermal measurement results IF the phones are in fact built identically and run identically. Some key parameters which will impact skin temperature are outlined as below:

1. Use-cases exercised on the phone.
2. Mechanical stack-ups and assembly procedures (i.e., both should be fully buttoned up, including the battery and the back cover installed)
3. Materials and geometries (e.g., thermal interface materials, shields, heat spreaders, PCB revision, chipset revision, eBOM, etc.)
4. Material, color, and finish of the phone skins (this impacts the emissivity setting of the IR camera).
5. Test location, test setups, test equipment, calibration, and measurement procedures
6. Software settings (Software build, LCD brightness level, RF power levels, etc.)
7. Test applications (and same revision) running for similar time periods.

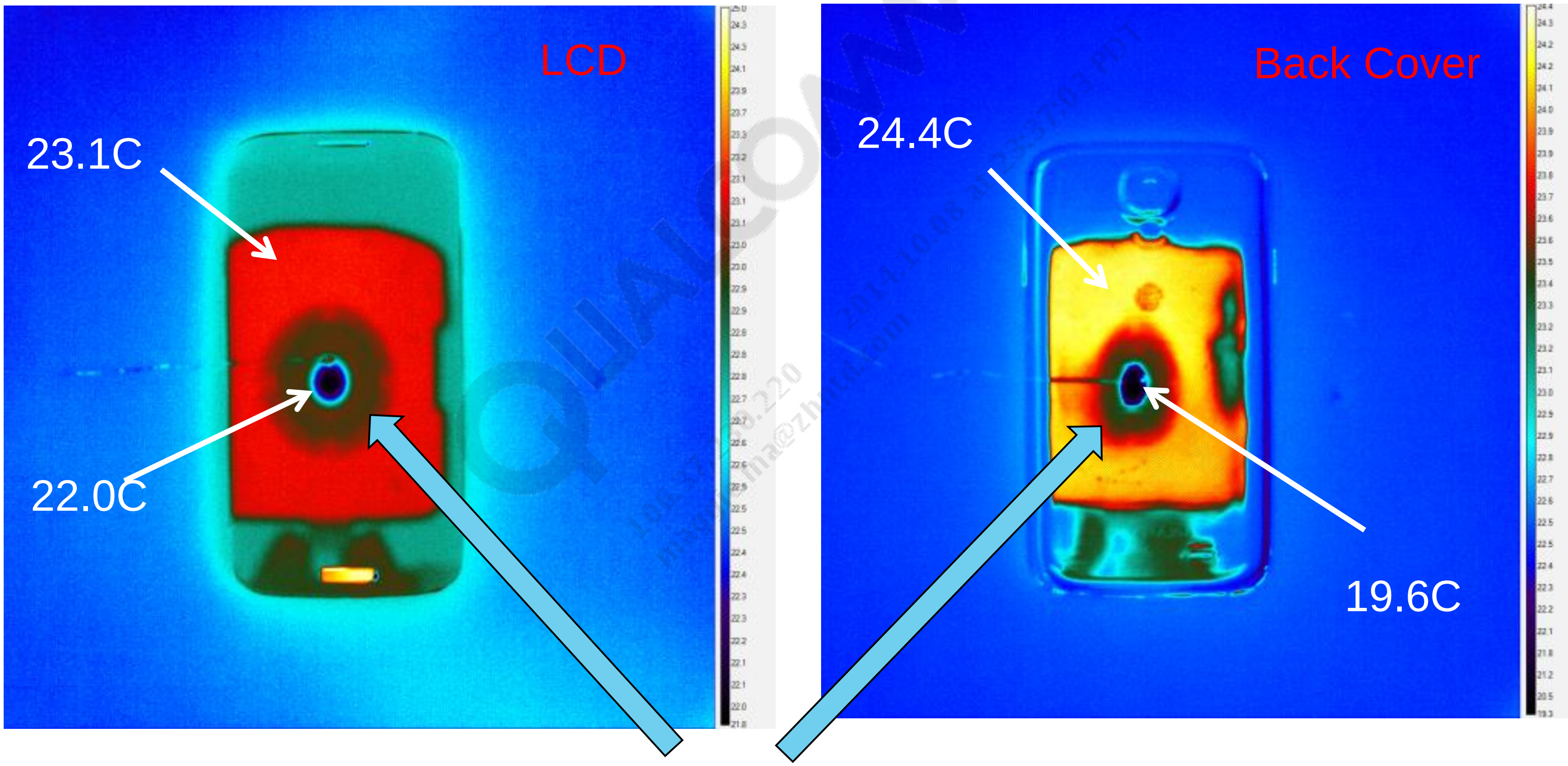
Section 6

Appendix A

Surface Reflection Removal

Surface Reflection Removal – Phone Turned Off (1 of 3)

Surface reflection from shining surface of the LCD and plastic cover has a significant effect on IR thermal imaging.

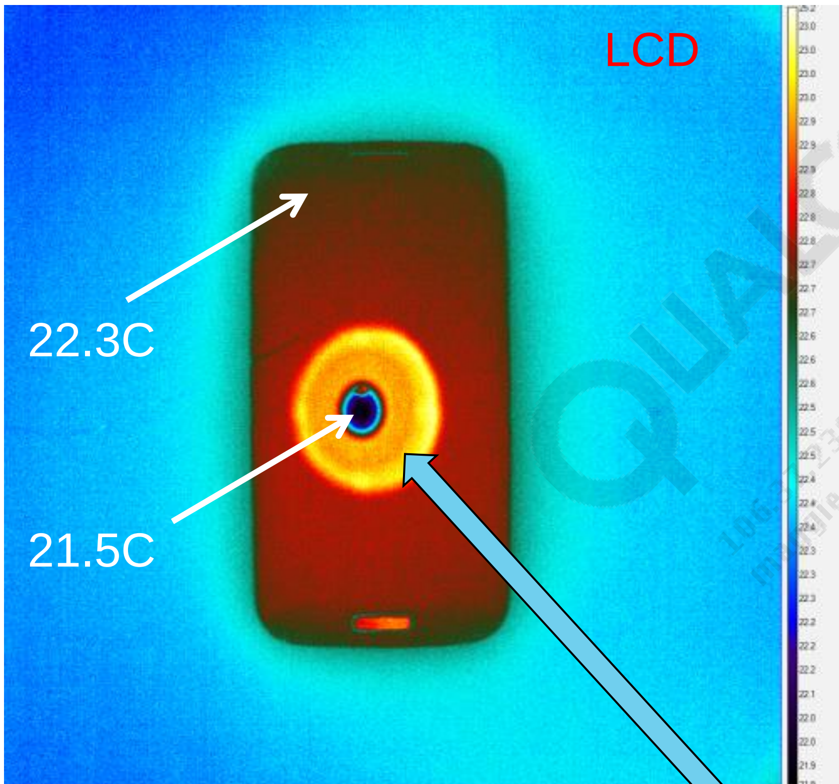


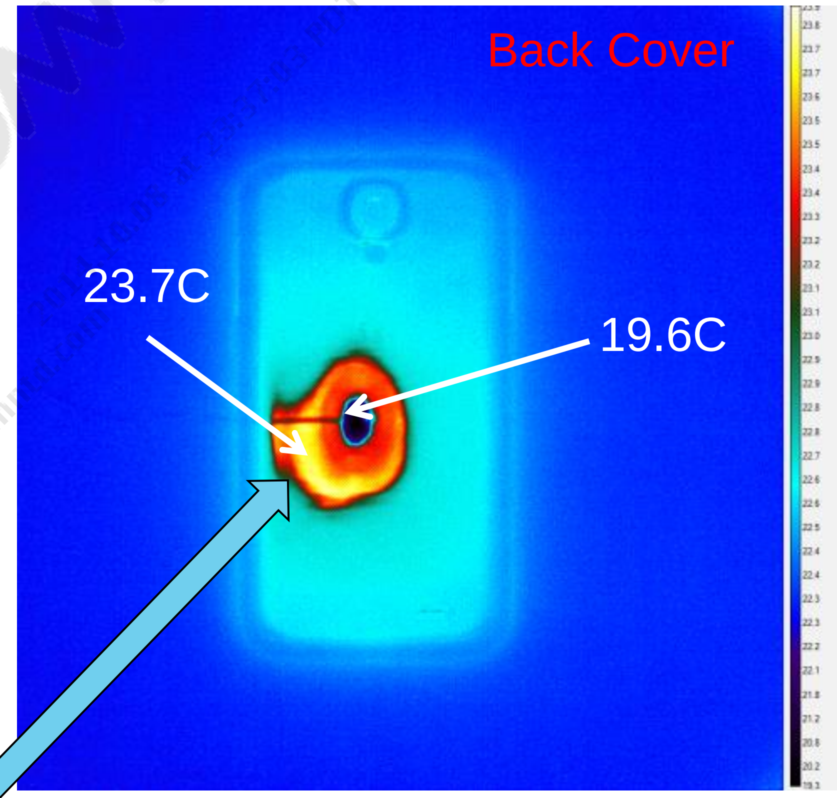
Abnormal temperature due surface reflection

The testing condition is with the phone turned off, placed horizontally, and with no black box covering the setup. (Front and back sides of phone are shown.) Notice the variations/noise in the temperature measurement data, even though the temperature reading should be fairly constant across the surface of phone.

Surface Reflection Removal – Phone Turned Off (2 of 3)

A black box can eliminate the reflection from the surrounding area, but cannot remove the surface reflection from the lens.



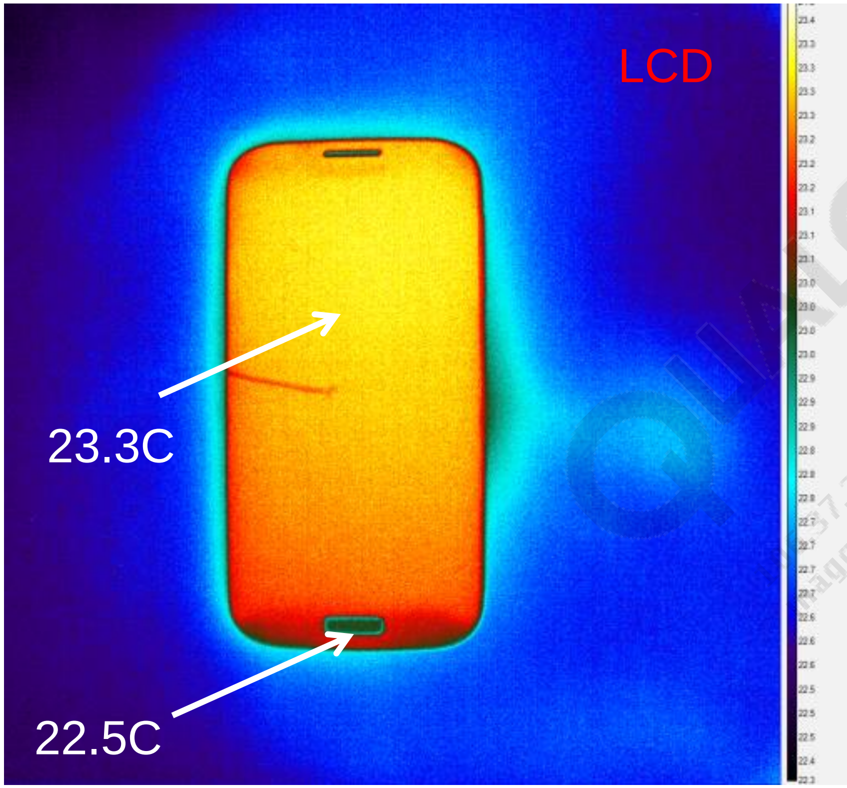


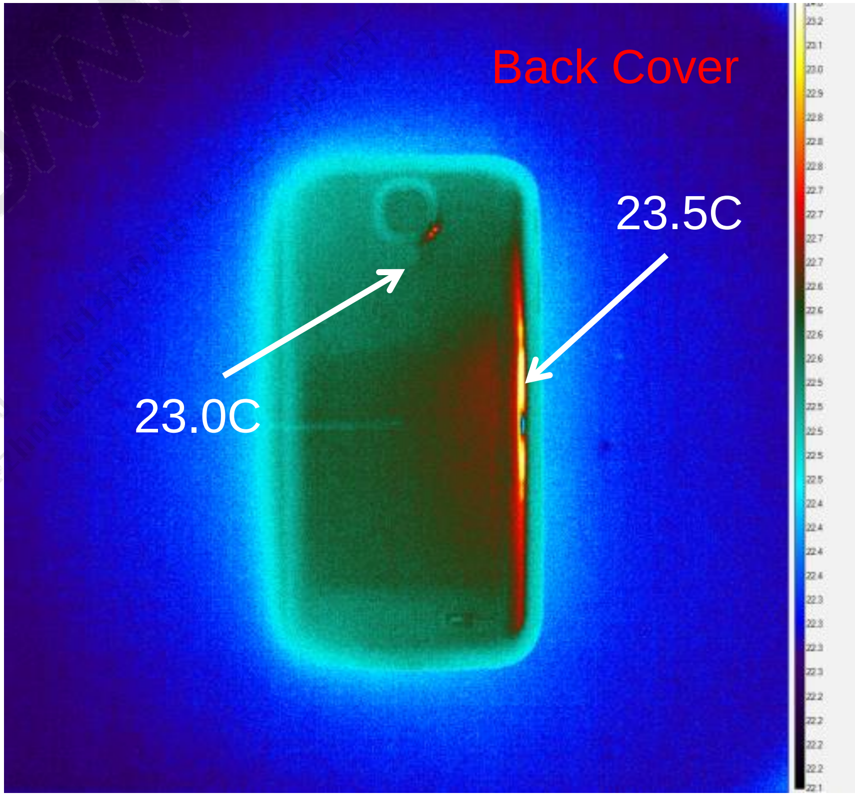
Abnormal temperature due surface reflection

The testing condition is with the phone turned off, placed horizontally, and with a black box covering the device. Notice that there are still variations/noise in the temperature measurement data.

Surface Reflection Removal – Phone Turned Off (3 of 3)

Titling the phone by 15° can completely remove surface reflection.

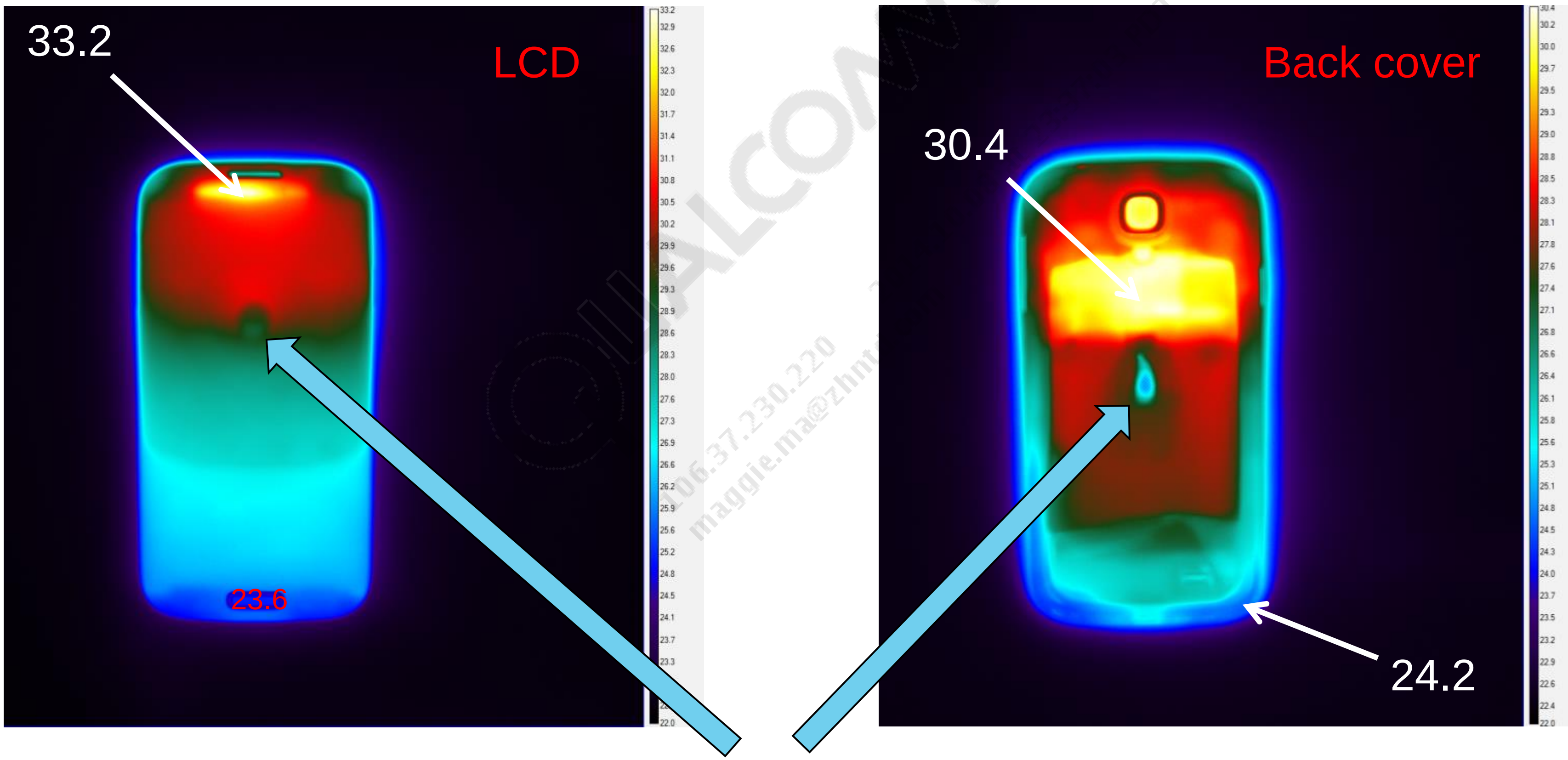




The testing condition is with the phone turned off, placed horizontally, and tilted by 15°.

Surface Reflection Removal – Phone Turned On (1 of 3)

Surface reflection from shining surface of the LCD and plastic cover has a significant effect on IR thermal imaging.

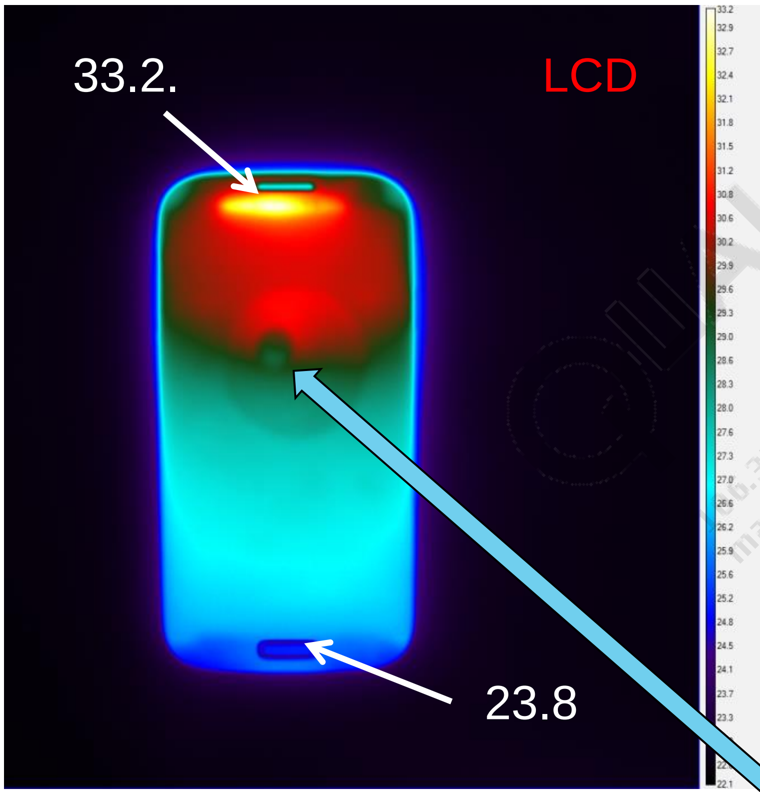


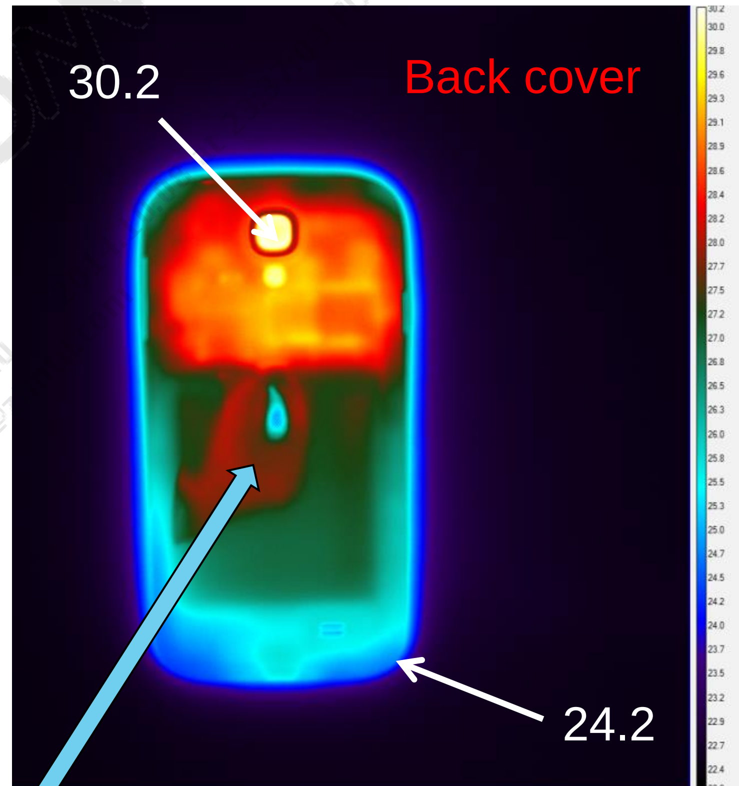
Abnormal temperature due surface reflection

The testing condition is with the phone turned on at idle state, placed horizontally, and with no black box covering the setup. (Front and back sides of phone are shown.)

Surface Reflection Removal – Phone Turned On (2 of 3)

Black box can eliminate the reflection from the surrounding but cannot remove the reflection from the lens.



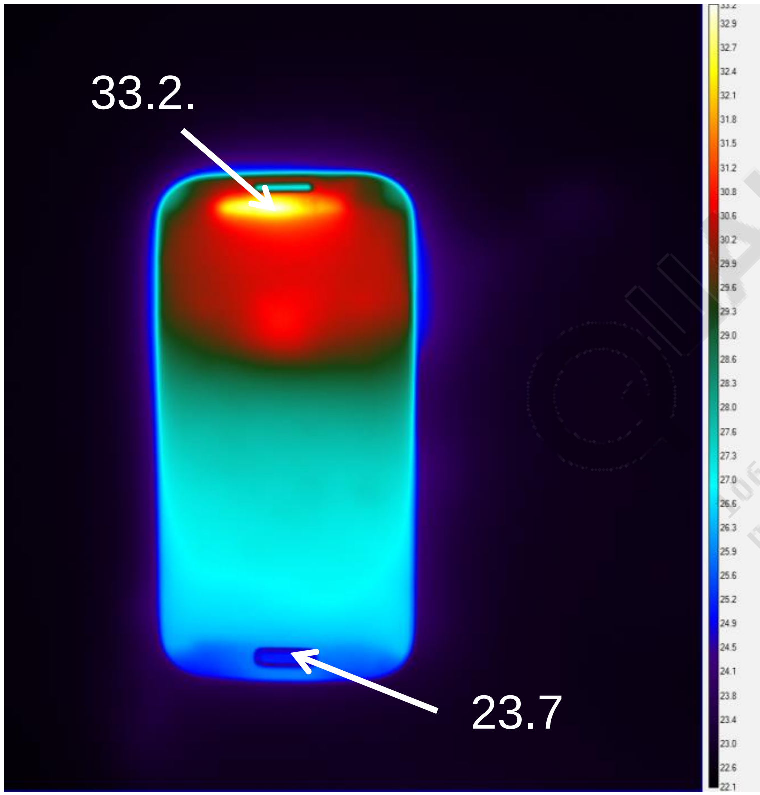


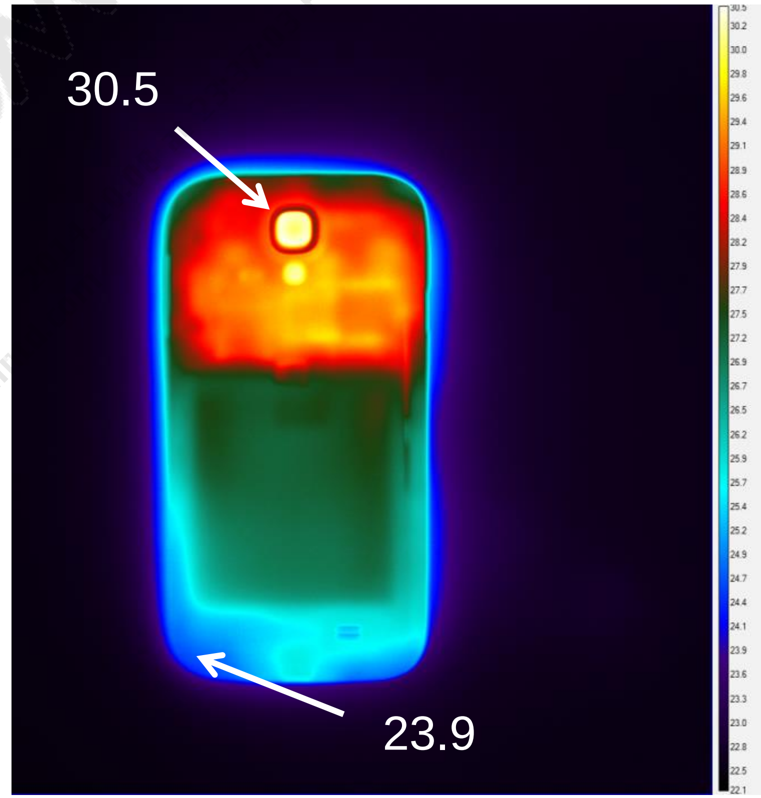
Abnormal temperature due surface reflection

The testing condition is with the phone turned on at idle state, placed horizontally, and with a black box covering the device.

Surface Reflection Removal – Phone Turned On (3 of 3)

Titling the sample by 15° can completely remove surface reflection.





The testing condition is with the phone turned on at idle state, placed horizontally, and tilted by 15°.

Section 7

Appendix B

Notes on Thermal Sensors and Standards

Thermal Sensors and Standards

1. Omega brand, special limits of error (SLE) – grade Type T thermocouples have ±0.5°C uncertainty, when there is no temperature gradient.
2. Pre-calibrated resistance temperature detectors (RTDs) can be purchased that are calibrated following methods traceable to the U.S. National Institutes of Standards and Technology (NIST), and are therefore very reliable. Qualcomm Technologies, Inc. (QTI) recommends using 4-wire RTDs of one of these types to measure temperature very accurately (typically to within ±0.15°C, plus any uncertainty due to the channel offsets of the electronic equipment used to read the RTDs, which is usually fairly small (within 0.1°C))
   - http://www.omega.com/pptst/SA1-RTD.html
   - Note that these will provide extremely accurate readings in a uniform-temperature environment, but if used in the presence of temperature gradients (such as to measure the temperature of a heated surface) then additional error is introduced.
3. If using thermocouples, QTI recommends using multiple thermocouples from at least two batches or spools of wire, and then average the readings of the sensors. Since the IR camera calibration measurement is done when the entire system has 'soaked' (been given time to equilibrate temperature) at ambient temperature, almost zero temperature gradients exist, and averaging the thermocouple sensor readings is a way to reduce the 'noise' or 'variation' in the data to achieve a more accurate estimate.

Thank You!

https://support.cdmatech.com