Short article name

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# Infrared Detection of Elevations in Mobile Phone Temperatures induced by Casings

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# Introduction

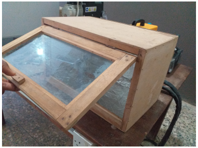
- Mobile phone manufacturers have recently integrated more functionalities in phones while reducing their sizes. The high-performance processors required for these new tasks come with a price: increased chip temperatures which give rise to thermal management related issues.
- The heat generated by the processors travel via heat transfer paths to the phone surfaces [5]. Since these surfaces come in contact with the user's skin, they need to be maintained below 45°C, which is the threshold temperature of pain for mobile usage [1], [2].
- Phone casings have become an important aspect of mobile phone technology in recent years. Mobile phone users procure casings for their devices in order to prevent damages to the screens due to falls or sudden impacts.

# Introduction (Contd.)

- A few studies have investigated the extent to which user experience and phone component integrity are affected by the heat generated by smartphones:
  - Kang et al. [4] studied several mobile phone operations to obtain temperatures, and phone surface thermograms. The study showed the effects of overheating in mobile devices and the need for adequate thermal management measures.
  - Gurrum et al. [3] developed a smartphone thermal model by analyzing a popular prototype and thermal tests with the model showed that the presence of stiffeners helped to facilitate faster heat flow via conduction to the phone outer surfaces, hence cooling the internal parts of mobile phones.
- Phone casings introduce an additional barrier in the route of heat dissipation, and this has not been considered in existing studies. Hence, this study investigates the changes in phone temperatures that are caused by a plastic casing when the phone is performing common tasks.

# Materials





Wooden cuboid test chamber

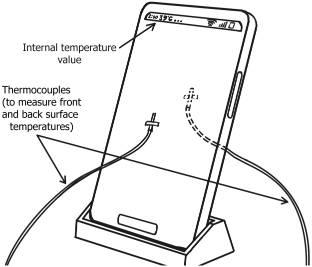
A plastic casing for the test phone

- Two smartphones of the same model
- The *Seek Compact* infrared thermal camera
- K-type thermocouple sensors
- A digital temperature logger

# The Test Setup



Test chamber with the mobile phone setup.




Measurement setup for each mobile phone.

# Method

- The two smartphones were placed side by side on an inclined stand to simultaneously measure their front and back surface temperatures while performing similar heavy tasks. Another thermocouple placed within the test chamber recorded the ambient temperature.
- The test smartphone was covered with a casing and the control phone was left without any casing.
- The IR camera was fixed in an opening in the test chamber to obtain thermograms of the smartphones at fixed time intervals.
- The internal (processor and battery) temperatures of the phones were measured by internal sensors in the phone and displayed by the *Cpu Monitor* mobile phone app(found on the Google Play Store).

# Method (Contd.)



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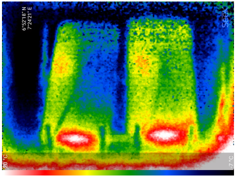
**The test operations carried out by the smartphones included:**

1. Online gaming: the popular PUBG MOBILE game was considered.
2. Audio voice calling: the default app on the phone was used.
3. Video streaming: the YouTube video streaming app (on Google Play Store) was employed.
4. Music playing: the Deezer music streaming app was used.

**IR thermography of casing effects on phone surface temperatures**

- To ensure regular thermal readings and minimize errors, all background apps were disabled, including auto-update, adaptive screen brightness and battery saving features to ensure identical operations in both test and control phones.
- The IR thermograms of the phone screen surfaces at the start of the tests, after 15 and 30 minutes were obtained.
- The test phone is on the right while the control phone is on the left of the IR images presented in this section.

# Phone surface thermograms during online gaming operations



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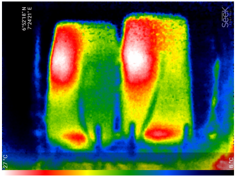

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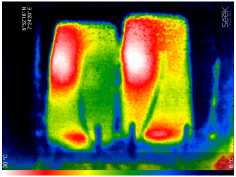
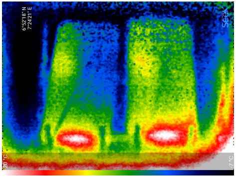


30 minutes

The white colour on the top left side of the smartphones represent the highest temperature region on the surface of the smartphones. This region is larger in the test phone (with casing) than in the control phone. The high surface temperatures indicated by this will usually cause discomfort on the hands of the user while gaming with these phones.

# Phone surface thermograms during voice calls





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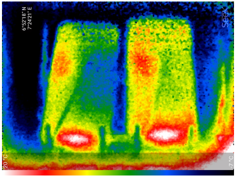

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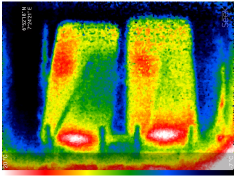
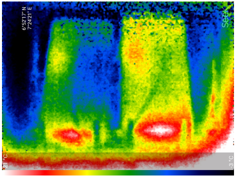


30 minutes

As observed in the online gaming case, the test phone temperatures generally appeared elevated compared to the control phone. However, the thermograms at 15 and 30 minutes show that the temperatures are more evenly distributed across the display surface compared to the previous case in which there were regions that showed appreciable temperature elevations.

# Phone surface thermograms for video streaming



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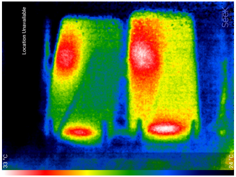

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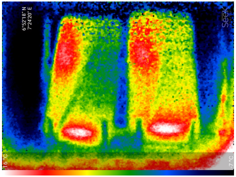
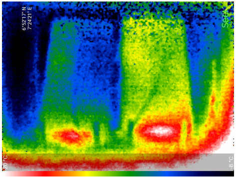


30 minutes

The position of the heat generating wireless network chipset on the phone processors are indicated by the regions of elevated temperatures. The network chipset is actively in use during this task, and its temperature initially rises fast from the start of the operation till 15 minutes into the operation, and reaches steady state between 15 and 30 minutes. However, this operation will degrade user experience because it generates a lot of heat in a short period, which the user would feel on his/her palm.

# Phone surface thermograms for music playing operations





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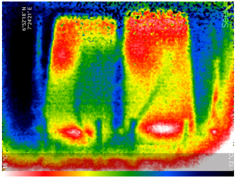

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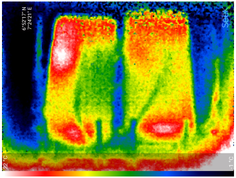
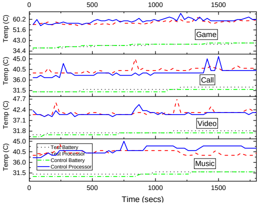


30 minutes

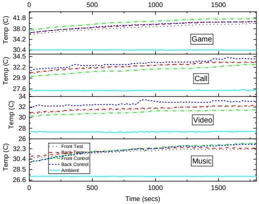
A slow rise in the surface temperatures was observed during the music playing operation. The thermograms indicate that the heat generated during this task is not significant as the patterns of the thermograms are not significantly altered.

# Effect of plastic phone casing on phone processor, battery and surface temperatures






Battery and Processor Temperatures




Surface and Ambient Temperatures

During the call, video and music tasks, the control phone back surface temperatures were higher than those of the test phone, revealing that the insulation provided by the plastic casing was sufficient for these tasks. The opposite was the case for the gaming task for which the casing was unable to suppress the excessive heat generated.

# Conclusion

- One can see from the thermograms that the task that gives the highest surface temperature distributions is online gaming, followed by video streaming, call making and then music playing. The test phones also appeared to be hotter than the control phones.
- The measured surface temperatures revealed that the phone casing inhibits the dissipation of heat generated within the smartphones. This is primarily due to the insulating property of the casing material.
- Consequently, the use of plastic phone casings will improve user experience by lowering the temperature of the phone surface which is in contact with the user's skin.
- However, this comes at the price of the excessive heating of phone internal parts, which is detrimental to the electronic components of the phone, which deteriorate under high temperature conditions.

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