

Experimental Evaluation of AMG8833 Thermal Sensor Performance for Hotspot Detection Under Different Distances and Lighting Conditions

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ABSTRACT

Early identification of abnormal temperature conditions is important for preventing overheating from developing into more serious thermal hazards. Thermal array sensors provide a non-contact approach for observing temperature distribution; however, their measurement behavior may vary with sensor-to-object distance and environmental conditions. This study experimentally evaluates the measurement performance of the AMG8833 thermal sensor for hotspot detection at different sensor-to-object distances and under different environmental lighting conditions. Measurements were conducted at distances of 5, 10, 15, 20, 30, 40, and 50 cm under bright, dim, and dark conditions. Each experimental combination was repeated five times, and one representative measurement was selected based on the relative stability of the temperature reading and hotspot pattern during the measurement process. The AMG8833 measurements were compared with a reference thermal gun to determine the measurement difference. The results showed that the mean measurement difference across the three conditions increased from 0.60°C at 5 cm to 2.73°C at 50 cm, with an R^2 of 0.956 for the linear fit of mean difference versus distance. The mean measurement differences across all tested distances were 1.59°C, 1.36°C, and 1.51°C under bright, dim, and dark conditions, respectively. Using a practical criterion of a mean measurement difference of $\leq 1^\circ\text{C}$ over the evaluated interval, the 5–20 cm interval was identified as the practical operating range for the tested hotspot measurement configuration. These results indicate that sensor-to-object distance produced a more pronounced variation in measurement difference than the tested environmental lighting conditions.

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1. INTRODUCTION

Temperature monitoring plays an important role in identifying abnormal thermal conditions before they develop into more serious equipment failures or fire hazards. Excessive temperature increases in electronic devices may degrade component performance, damage electronic components, and increase the risk of fire [1], [2]. When an abnormal increase in temperature is not detected at an early stage, localized high-temperature areas or hotspots may develop and potentially lead to more serious thermal hazards [3]. This condition is

particularly relevant in enclosed environments containing continuously operating electronic equipment, such as laboratories, server rooms, and data centers [4]. Therefore, the ability to identify localized temperature variations without direct contact is important for supporting early thermal monitoring. Conventional temperature sensors generally provide temperature measurements at a specific sensing point and may not adequately represent the spatial distribution of temperature across an observed object. In contrast, thermal array sensors can acquire temperature information from multiple sensing elements simultaneously, allowing localized thermal variations to be represented as a thermal distribution. This characteristic makes thermal array sensors potentially useful for non-contact hotspot detection and monitoring applications. The application of thermal sensing for non-contact monitoring has previously been demonstrated for machine condition monitoring using a thermal camera and a web-based application [5].

One thermal array sensor that can be utilized for this purpose is the AMG8833. The sensor provides thermal information from multiple pixels, enabling the detection of localized temperature variations on the surface of an observed object. Previous research has evaluated the accuracy of the AMG8833 for temperature measurement and compared its performance with other non-contact temperature sensors [6], [7]. Studies using infrared thermal array sensors have also demonstrated their capability to acquire spatial temperature information for monitoring and positioning applications [8]. These studies demonstrate the potential of the AMG8833 for temperature measurement applications. However, the practical performance of a thermal array sensor may also depend on the measurement configuration. In hotspot monitoring applications, the distance between the sensor and the observed object is one factor that may influence the temperature measurement because changes in distance affect the spatial area represented by the sensor's field of view [9], [10].

In addition to measurement distance, environmental conditions may also influence the observed thermal measurement. This study considers three lighting conditions, namely bright, dim, and dark conditions, to evaluate whether the AMG8833 produces consistent temperature measurements under different experimental environments. Although visible lighting does not constitute the primary sensing mechanism of a thermal sensor, testing under different lighting conditions provides an additional evaluation of the sensor's measurement behavior within the experimental setup.

Previous research has demonstrated the use of sensor-based monitoring systems for fire and thermal conditions. Zaputra et al. developed a fire detection system capable of monitoring flame, gas, voltage, current, and power parameters, with the monitoring results displayed through a website and notifications delivered via WhatsApp [11]. Other research has developed fire monitoring systems by integrating flame, smoke, and temperature sensors with automatic response mechanisms [12], while smoke- and flame-based systems have also been implemented with SMS notification capabilities [13]. These studies demonstrate the application of multiple sensing technologies for fire monitoring. However, flame and gas sensors are generally more suitable for detecting fire-related conditions after the occurrence of flames or gas leakage, rather than characterizing localized temperature increases during the early overheating stage [14]. Thermal sensing therefore provides an alternative approach for observing temperature variations before a visible flame occurs. In contrast to conventional fire detection approaches that primarily rely on flame, smoke, or gas detection, thermal array sensing can provide information regarding the spatial distribution of temperature. Although previous studies have demonstrated the temperature measurement capability of the AMG8833 [6], [7], further experimental evaluation is required to investigate its measurement behavior for hotspot detection across different sensor-to-object distances and lighting conditions.

Previous studies on non-contact infrared thermometry have also reported that measurement results can vary with measurement distance and other measurement conditions, emphasizing the importance of controlling the measurement configuration when evaluating non-contact thermal sensors [15]. Therefore, this study focuses on the experimental evaluation of the AMG8833 thermal sensor for hotspot detection. Temperature measurements obtained from the AMG8833 are compared with measurements from a thermal gun as a reference to determine the measurement difference at several sensor-to-object distances. The evaluation is conducted under bright, dim, and dark lighting conditions. The analysis is intended to identify the measurement range in which the AMG8833 provides relatively small temperature differences and to determine an effective distance for hotspot measurement under the tested experimental conditions. The objective of this study is to evaluate the measurement performance of the AMG8833 thermal sensor for hotspot detection based on measurement distance and lighting condition, quantify the difference between AMG8833 and reference temperature measurements, and determine the effective sensor-to-object distance for hotspot measurement.

2. RESEARCH METHOD

2.1. Research Design

This study employed an experimental method to evaluate the measurement performance of the AMG8833 thermal array sensor for hotspot detection. The evaluation was performed by comparing the temperature measured by the AMG8833 with the temperature obtained from an industrial thermal gun as a

reference instrument. Two main experimental variables were considered: the sensor-to-object measurement distance and the surrounding lighting condition. The measurement distances were set at 5, 10, 15, 20, 30, 40, and 50 cm. The experiment was conducted under three lighting conditions, namely bright, dim, and dark. The bright condition was conducted between 09:00 and 10:00, the dim condition between 17:00 and 18:00, and the dark condition between 21:00 and 22:00.

Each combination of measurement distance and lighting condition was tested five times. From the five repeated measurements, one representative measurement result was recorded for each distance and subsequently used in the analysis. Therefore, the final analysis consisted of one representative measurement for each of the seven distances under each lighting condition.

2.2. Measurement Setup

The hardware of tools system consisted of an ESP32 microcontroller, AMG8833 thermal array sensor, flame sensor, TFT LCD, and microSD card. The AMG8833 served as the primary sensor evaluated in this study, while the ESP32 was used to acquire and process the thermal measurement data. The AMG8833 is an infrared thermal array sensor consisting of 64 sensing elements arranged in an 8×8 matrix. The sensor provides temperature information from multiple pixels, allowing the thermal distribution of an observed object to be represented. This characteristic enables the sensor to identify localized areas with higher temperatures, which are used as the hotspot information in this study. The flame sensor, TFT LCD, and microSD card functioned as supporting components of the overall monitoring prototype and were not used as the primary variables in the evaluation of AMG8833 measurement performance.

A Benetech GM320 infrared thermometer was used as the reference instrument for comparative temperature measurements. According to the manufacturer's specification, the GM320 has a temperature measurement range of -50°C to 400°C . Its stated accuracy is $\pm 1.5^{\circ}\text{C}$ or $\pm 1.5\%$ for measurements from 0°C to 400°C , and $\pm 5^{\circ}\text{C}$ for measurements from -50°C to 0°C . The instrument has a resolution of $0.1^{\circ}\text{C}/0.1^{\circ}\text{F}$, a stated repeatability of 1% of the reading or 1°C , and a response time of 500 ms (95%). The GM320 has a spectral response range of 5–14 μm , a preset emissivity of 0.95, and a distance-to-spot ratio (D:S) of 12:1. No additional calibration or adjustment was performed by the authors before the experiment.

During the comparative measurement, the GM320 was directed toward the same hotspot region of the smartphone that was observed by the AMG8833. The temperature reading from the GM320 was recorded at each sensor-to-object distance and subsequently compared with the maximum temperature obtained from the AMG8833. This procedure was applied consistently across the tested measurement distances and experimental conditions.



Fig. 1 Hardware Implementation

2.3. Test Object and Hotspot Simulation

The Poco F7 smartphone was used as the test object for hotspot simulation. To generate a consistent thermal workload, Mobile Legends was operated for approximately 25–30 minutes in each experimental session. The gameplay workload and device configuration were kept consistent across all experiments. All available game graphics and performance-related settings were configured to their highest available levels, including the ultra graphics mode, to impose a relatively high processing load on the smartphone and induce a measurable hotspot. The smartphone was operated under this workload before the measurement process was conducted. Because the hotspot temperature could fluctuate during operation, the thermal response was monitored during the measurement process using both the temperature readings and the thermal heatmap pattern. A measurement was considered representative when the temperature reading and the location and pattern of the hotspot appeared relatively stable, consistent with the representative-measurement procedure described in Section 2.6.



Fig. 2 Object of Simulation

2.4. Measurement Configuration

The effect of sensor-to-object distance was evaluated at seven measurement distances: 5, 10, 15, 20, 30, 40, and 50 cm. At each distance, the AMG8833 was positioned facing the hotspot area of the smartphone. The distance was measured between the sensing position of the AMG8833 and the surface of the smartphone. The same target area was subsequently measured using the industrial thermal gun as the reference instrument. The variation in measurement distance was intended to evaluate the ability of the AMG8833 to measure the hotspot temperature at different observation ranges. The results obtained at short distances were compared with those obtained at longer distances to determine the effective measurement range of the sensor.

2.5. Environmental Conditions

The experiment was conducted in an enclosed indoor room using natural sunlight entering through the room openings as the primary source of illumination. No additional artificial lighting was used during the measurements. Other environmental factors that could directly affect the thermal condition of the test object were also minimized; no air conditioning or additional fan was used during the experiment. Three environmental conditions were considered: bright, dim, and dark. The bright condition was conducted between 09:00 and 10:00, the dim condition between 17:00 and 18:00, and the dark condition between 21:00 and 22:00. Illumination was not quantitatively measured using a lux meter; therefore, the terms bright, dim, and dark refer to the naturally occurring illumination conditions observed during the specified measurement periods. Because the three conditions were tested at different times of day, differences in ambient temperature, environmental conditions, and the thermal state of the smartphone could not be completely separated from the lighting condition. Therefore, comparisons among the bright, dim, and dark conditions are interpreted as comparisons under the tested environmental conditions and measurement periods rather than as an isolated effect of illumination.



Fig. 3 Documentation of The Experiment in Each Condition

2.6. Experimental Procedure

The measurement procedure was conducted according to the following stages:

1. The Poco F7 smartphone was operated by running resource-heavy application to generate a localized hotspot.
2. The smartphone was operated until the hotspot temperature began to stabilize at approximately more than 30°C.
3. The experimental condition was established according to the specified lighting condition.
4. The AMG8833 was positioned at the predetermined distance of 5, 10, 15, 20, 30, 40, or 50 cm from the smartphone.
5. The thermal measurement from the AMG8833 was recorded.
6. The same hotspot area was measured using the industrial thermal gun.
7. The measurement distances were tested sequentially from 5 to 50 cm (5, 10, 15, 20, 30, 40, and 50 cm) without randomization. The same sequence was consistently applied across all experimental conditions and repeated measurements.

8. The measurement procedure was repeated five times for each distance and lighting condition. During each measurement, the temperature readings and thermal heatmap pattern were observed, as the smartphone hotspot could fluctuate during operation.
9. One representative measurement was selected from the five repetitions when the temperature reading and the location and pattern of the hotspot appeared relatively stable. The selection was performed during the measurement process and before comparison with the reference thermal gun. The procedure was repeated for all seven measurement distances and three environmental conditions.

The resulting data were then used to calculate the temperature difference between the AMG8833 and the industrial thermal gun.

2.7. Temperature Difference Analysis

The difference between the AMG8833 measurement and the reference thermal gun measurement was calculated using the absolute difference:

$$D = T_A - T_{Ref} \quad (1)$$

In equation (1) where D is the absolute temperature difference in $^{\circ}\text{C}$, T_A is the temperature measured by the AMG8833, and T_{Ref} is the temperature measured by the industrial thermal gun. The calculated difference was used to evaluate the agreement between the AMG8833 and the reference instrument at each measurement distance and lighting condition. A smaller value of (D) indicates that the AMG8833 measurement is closer to the reference measurement.

The average temperature difference for a specific measurement range was calculated from the representative measurement differences recorded at the corresponding distances:

$$Da = \frac{\sum_{i=1}^n D_i}{n} \quad (2)$$

In equation (2) where Da is the average temperature difference, D_i is the temperature difference at the (i)-th measurement distance, and (n) is the number of measurement distances included in the evaluated range. The measurement differences obtained at 5–20 cm were subsequently compared with those obtained at longer distances to determine the effective measurement range of the AMG8833 under the tested experimental conditions.

3. RESULT AND DISCUSSION

3.1. Bright Condition

The measurement results under bright conditions are presented in Table 1. The experiment was conducted at seven sensor-to-object distances ranging from 5 cm to 50 cm. The temperature measured by the AMG8833 was compared with the temperature obtained from the industrial thermal gun.

Table 1. Temperature Measurement Results under Bright Conditions

Distance	AMG8833 ($^{\circ}\text{C}$)	Thermal Gun ($^{\circ}\text{C}$)	Difference ($^{\circ}\text{C}$)
5 cm	40.3	40.7	0.4
10 cm	39.8	40.1	0.3
15 cm	39.5	40.8	1.3
20 cm	39.3	40.5	1.2
30 cm	38.8	39.8	1.0
40 cm	37.0	39.7	2.7
50 cm	35.3	39.5	4.2

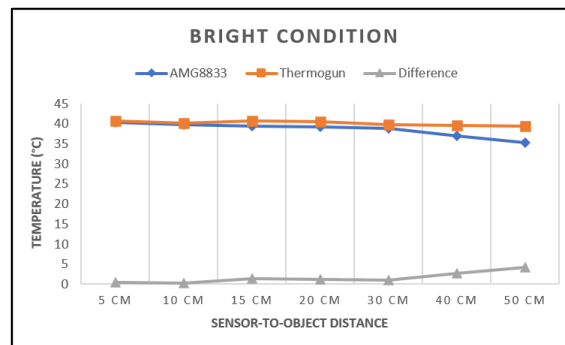


Fig. 4 Bright Condition Graph

Under bright conditions, the AMG8833 recorded a maximum temperature of 40.3°C and a minimum temperature of 35.3°C, while the thermal gun recorded a maximum of 40.8°C and a minimum of 39.5°C. The measurement difference was relatively small at distances of 5 and 10 cm, with values of 0.4°C and 0.3°C, respectively. At 15 and 20 cm, the differences increased to 1.3°C and 1.2°C.

A more pronounced difference was observed at longer distances. At 30 cm, the difference was 1.0°C, increasing to 2.7°C at 40 cm and 4.2°C at 50 cm. These results indicate that the AMG8833 measurement increasingly deviated from the thermal gun measurement as the sensor-to-object distance increased.

For the 5–20 cm measurement range, the average difference was 0.8°C. This indicates that the AMG8833 provided relatively close temperature measurements to the reference instrument within this range. In contrast, the increasing difference at distances above 20 cm indicates a reduction in measurement agreement at longer observation distances.

3.2. Dim Condition

The measurement results under dim conditions are presented in Table 2.

Table 2. Temperature Measurement Results under Dim Conditions

Distance	AMG8833 (°C)	Thermal Gun (°C)	Difference (°C)
5 cm	40.3	41.2	0.9
10 cm	40.3	41.1	0.8
15 cm	40.0	41.3	1.3
20 cm	39.8	40.8	1.0
30 cm	39.3	40.7	1.4
40 cm	38.0	40.3	2.3
50 cm	36.8	38.6	1.8

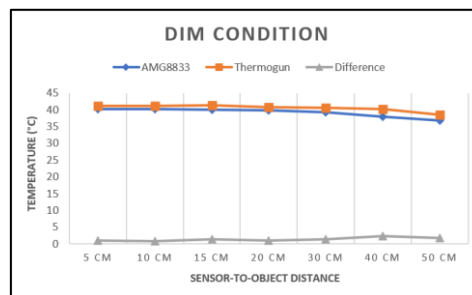


Fig. 5 Dim Condition Graph

Under dim conditions, the AMG8833 recorded a maximum temperature of 40.3°C and a minimum temperature of 36.8°C. The thermal gun recorded a maximum of 41.3°C and a minimum of 38.6°C. The measurement differences at 5, 10, 15, and 20 cm were 0.9°C, 0.8°C, 1.3°C, and 1.0°C, respectively.

Similar to the bright condition, the measurement difference generally increased at longer distances. The difference reached 2.3°C at 40 cm, while the difference at 50 cm was 1.8°C. The average difference within the 5–20 cm range was 1.0°C.

The results indicate that the AMG8833 maintained relatively close agreement with the reference measurement within the short-distance range. At distances beyond 20 cm, the difference generally became larger, indicating that the measurement distance had a more noticeable effect on the observed hotspot temperature.

3.3. Dark Condition

The measurement results under dark conditions are presented in Table 3.

Table 3. Temperature Measurement Results under Dark Conditions

Distance	AMG8833 (°C)	Thermal Gun (°C)	Difference (°C)
5 cm	41.5	42.0	0.5
10 cm	41.5	42.2	0.7
15 cm	41.0	42.2	1.2
20 cm	40.5	42.0	1.5
30 cm	39.0	41.2	2.2
40 cm	37.8	40.1	2.3

Distance	AMG8833 (°C)	Thermal Gun (°C)	Difference (°C)
50 cm	36.0	38.2	2.2

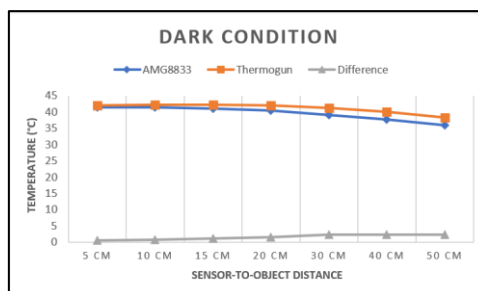


Fig. 6 Dark Condition Graph

Under dark conditions, the AMG8833 measured temperatures ranging from 36.0°C to 41.5°C, while the thermal gun measured temperatures ranging from 38.2°C to 42.2°C. The smallest measurement differences were obtained at 5 and 10 cm, with values of 0.5°C and 0.7°C, respectively.

At 15 and 20 cm, the differences increased to 1.2°C and 1.5°C. At longer distances, the differences were 2.2°C at 30 cm, 2.3°C at 40 cm, and 2.2°C at 50 cm. The average difference within the 5–20 cm range was approximately 1.0°C.

The results under dark conditions show a similar tendency to the bright and dim conditions, where the temperature difference between the AMG8833 and the reference instrument was generally smaller at shorter distances. The results also indicate that the AMG8833 remained capable of detecting the hotspot at longer distances, although the agreement with the reference measurement decreased.

3.4. Comparison of Measurement Differences Across Conditions

The measurement differences obtained under the three lighting conditions are summarized in Table 4.

Table 4. Comparison of Measurement Differences under Different Lighting Conditions

Distance	Bright (°C)	Dim (°C)	Dark (°C)
5 cm	0.4	0.9	0.5
10 cm	0.3	0.8	0.7
15 cm	1.3	1.3	1.2
20 cm	1.2	1.0	1.5
30 cm	1.0	1.4	2.2
40 cm	2.7	2.3	2.3
50 cm	4.2	1.8	2.2
Average (5-20cm)	0.8	1.0	1.0

The smallest measurement differences were generally observed at 5 and 10 cm, where all values remained below 1°C across the three tested lighting conditions. At 15 and 20 cm, some differences exceeded 1°C but remained relatively close to the reference values. The average measurement differences over the 5–20 cm range were 0.8°C, 1.0°C, and approximately 1.0°C under bright, dim, and dark conditions, respectively. Beyond 20 cm, the difference became more pronounced, with the largest value of 4.2°C observed under bright conditions at 50 cm.

A descriptive comparison was performed to examine the relative influence of measurement distance and lighting condition. The mean measurement difference across the three conditions increased from 0.60°C at 5 cm to 2.73°C at 50 cm. A linear fit of the mean measurement difference versus sensor-to-object distance produced a positive slope of approximately 0.049°C/cm with an R^2 of 0.956, indicating a strong increasing trend with distance. In comparison, the mean measurement differences across all tested distances were 1.59°C, 1.36°C, and 1.51°C for bright, dim, and dark conditions, respectively. These results indicate that measurement distance showed a more pronounced pattern of change in measurement difference than the tested lighting conditions.

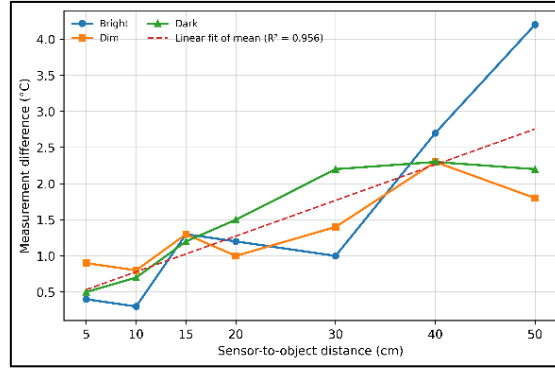


Fig. 7 Measurement Differences at Various Sensor-to-Object Distances

This behavior can be explained by the spatial characteristics of the AMG8833, which uses an 8×8 array consisting of 64 thermal sensing elements. As the sensor-to-object distance increases, the physical area represented within the field of view becomes larger, while the smartphone hotspot remains relatively localized. Consequently, the hotspot occupies a smaller portion of the sensing array, allowing surrounding lower-temperature areas to increasingly influence the detected maximum temperature. This spatial averaging effect provides a physical explanation for the increasing measurement difference observed at longer distances.

3.5. Effective Measurement Range

Based on the measurement results, the AMG8833 demonstrated relatively close agreement with the industrial thermal gun at short sensor-to-object distances. Across the three lighting conditions, the average measurement differences within the 5–20 cm range were 0.8°C , 1.0°C , and approximately 1.0°C for bright, dim, and dark conditions, respectively. These average values were calculated from the measurement differences obtained at 5, 10, 15, and 20 cm for each lighting condition.

The measurement differences generally increased when the distance exceeded 20 cm. The largest deviation was observed under bright conditions at 50 cm, where the difference reached 4.2°C . Although the AMG8833 was still capable of detecting the hotspot at longer distances, the measured temperature became less comparable with the reference instrument.

In this study, a mean measurement difference of $\leq 1^\circ\text{C}$ across a distance interval was used as the practical criterion for identifying the short-range operating range. The 5–20 cm interval produced mean measurement differences of 0.8°C under bright conditions, 1.0°C under dim conditions, and approximately 1.0°C under dark conditions. Although an individual measurement beyond 20 cm could also produce a difference of $\leq 1^\circ\text{C}$, such as the 1.0°C difference observed at 30 cm under bright conditions, this result was not consistent across the other lighting conditions. Therefore, the 5–20 cm interval is considered the practical operating range for the tested hotspot measurement configuration based on its mean measurement difference across all three lighting conditions.

3.6. Discussion

The experimental results indicate that the measurement behavior of the AMG8833 was more strongly associated with sensor-to-object distance than with the tested lighting conditions. The descriptive analysis showed an increasing mean measurement difference from 0.60°C at 5 cm to 2.73°C at 50 cm, with a linear-fit R^2 of 0.956. In contrast, the mean measurement differences across all tested distances were 1.59°C , 1.36°C , and 1.51°C under bright, dim, and dark conditions, respectively. This suggests that changes in measurement distance produced a more pronounced variation in the measurement difference than the differences observed among the three experimental lighting conditions.

The distance-dependent behavior can be explained by the spatial characteristics of the AMG8833. The sensor uses an 8×8 thermal array with a 60° viewing angle. Based on a simple geometric approximation, the field-of-view width can be estimated as

$$W = 2d \tan(30^\circ) \quad (3)$$

resulting in coverage widths of approximately 5.77 cm at 5 cm and 57.74 cm at 50 cm. Thus, the estimated spatial coverage of each pixel increases from approximately 0.72 cm to 7.22 cm over this distance range, this calculation based on equation (4) below.

$$W_{\text{pixel}} = \frac{W}{8} \quad (4)$$

Considering that the POCO F7 has a width of 7.79 cm, the hotspot occupies a relatively smaller portion of the sensing area as the distance increases. This can cause the detected maximum temperature to be increasingly influenced by surrounding lower-temperature areas, which helps explain the larger measurement differences observed at longer distances.

The lighting comparison should, however, be interpreted with caution. The bright, dim, and dark conditions were conducted at different times of day, namely 09:00–10:00, 17:00–18:00, and 21:00–22:00, respectively. Therefore, the lighting condition was not independently controlled from other environmental factors such as ambient temperature and the thermal state of the smartphone. Illumination was also not quantitatively measured in lux. The comparison therefore represents different experimental environmental conditions rather than an isolated effect of visible illumination on the AMG8833. Nevertheless, the relatively similar measurement differences obtained across the three conditions within the 5–20 cm interval indicate that the sensor maintained comparable measurement behavior under the tested conditions.

The use of a smartphone operated with a consistent high workload also introduced a dynamic thermal condition. Five repeated measurements were performed for each experimental combination, and one representative measurement was selected during the measurement process based on the relative stability of the temperature reading and hotspot pattern. This approach was used because the smartphone temperature could fluctuate during continuous gameplay. Therefore, the reported results should be interpreted as representative measurement differences for the tested configuration rather than a statistical estimate of repeatability or absolute sensor accuracy. The reference thermal gun was used as a comparison instrument, and the observed absolute differences describe measurement agreement between the two instruments rather than establishing the absolute accuracy of the AMG8833. Non-contact infrared temperature measurements can be affected by measurement configuration and other sources of uncertainty; therefore, the observed difference should be interpreted within the context of the experimental setup [16].

4. CONCLUSION

This study evaluated the measurement performance of the AMG8833 thermal sensor for hotspot detection at different sensor-to-object distances under bright, dim, and dark environmental conditions. The results showed that measurement difference generally increased with distance, with the mean difference increasing from 0.60°C at 5 cm to 2.73°C at 50 cm ($R^2 = 0.956$). In comparison, the mean differences under bright, dim, and dark conditions were 1.59°C, 1.36°C, and 1.51°C, respectively, indicating that sensor-to-object distance produced a more pronounced variation than the tested environmental lighting conditions. Based on a practical criterion of a mean measurement difference of $\leq 1^\circ\text{C}$, the 5–20 cm interval was identified as the practical operating range for the tested configuration. The increasing difference at longer distances can be associated with the spatial characteristics of the AMG8833 8×8 thermal array, where the hotspot occupies a smaller portion of the sensing area as distance increases. However, the lighting results should be interpreted cautiously because the tested conditions were conducted at different times of day and illumination was not quantitatively measured. Further studies should use controlled lighting and more stable hotspot conditions to improve the evaluation of measurement variability and repeatability.

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6. AUTHOR CONTRIBUTIONS

- Rizky Ramadhani: Conceptualization, Methodology, Investigation, Data Curation, Formal Analysis, Visualization, Writing – Original Draft.
- Adi Widiatmoko Wastumirad: Supervision, Methodology, Validation, Writing – Review & Editing.
- Tri Istiana: Supervision, Validation, Writing – Review & Editing.
- Agustina Rachmawardani: Validation, Writing – Review & Editing.
- Anton Widodo: Validation, Writing – Review & Editing.

7. CONFLICT OF INTEREST

Conflict of interest: The authors declare no conflict of interest.

8. DATA AVAILABILITY STATEMENT

Data Availability Statement: The data supporting the findings of this study are available from the corresponding author upon reasonable request.

9. GENERATIVE AI USE STATEMENT

Generative AI Use Statement: Generative AI tools were used to assist with the translation of the manuscript from Indonesian to English. The authors reviewed and verified all AI-assisted text and take full responsibility for the final content.

10. ETHICS APPROVAL

Ethics approval: Not applicable.

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