



Improve Temperature Accuracy By Minimize Heat Transfer from Heat Sources to Sensor module

Application Note MI.AN49

Revision 0.0.1 – Nov 2024

1. INTRODUCTION

Heat management is essential in any electronic system design, particularly when heat-sensitive devices, such as thermal sensors, are involved. If heat is not properly dissipated, it can result in thermal stress, reduced efficiency, sensing drift, or even failure of these sensitive components. Therefore, understanding how to prevent or minimize heat transfer to these devices is crucial for ensuring product reliability and longevity.

This application note outlines several methods to protect sensor modules from heat sources on a PCB or within an enclosure, focusing on practical strategies that can be integrated into the design process.

2. THERMAL BEHAVIOR OF SENSOR MODULE

Typically, this manifests in how the sensor responds to changes in temperature and the surrounding environmental conditions

2.1. Overview

2.1.1. Set-up

Circular 6cm Black Body Set to 90°C.

The sensor is positioned 42cm away from the black body.

PTC (Heating Element) is set to 60°C.

Firmware Averaging is set to 4.

PTAT Rolling Average is set to 1.

Various insulator thicknesses are used, ranging from 0.1mm to 1.6mm which are conveyed in Fig. 1.

2.1.2. Capturing

The sensor starts at room temperature.

The PTC slides into contact with the sensor using different insulator thicknesses until the PTAT value stabilizes.

The PTC is then moved back, and the capture ends once the sensor reaches room temperature.

2.1.3. Result

Heat transfer through conduction from a nearby heat source can lead to a rise in sensor temperature. This may cause the sensor to register a temperature lower than the actual ambient temperature, leading to errors in measurement. The rate of heat transfer

depends on the material properties and the distance between the heat source and the sensor.

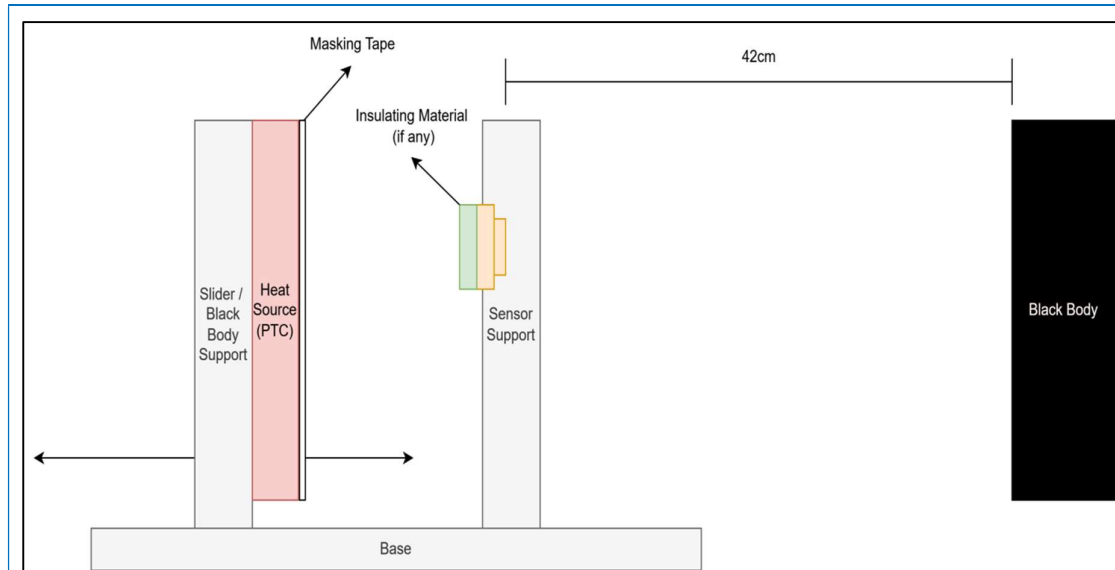


Fig. 1. Measurement set-up for sensor on PTAT heat up by heat source.

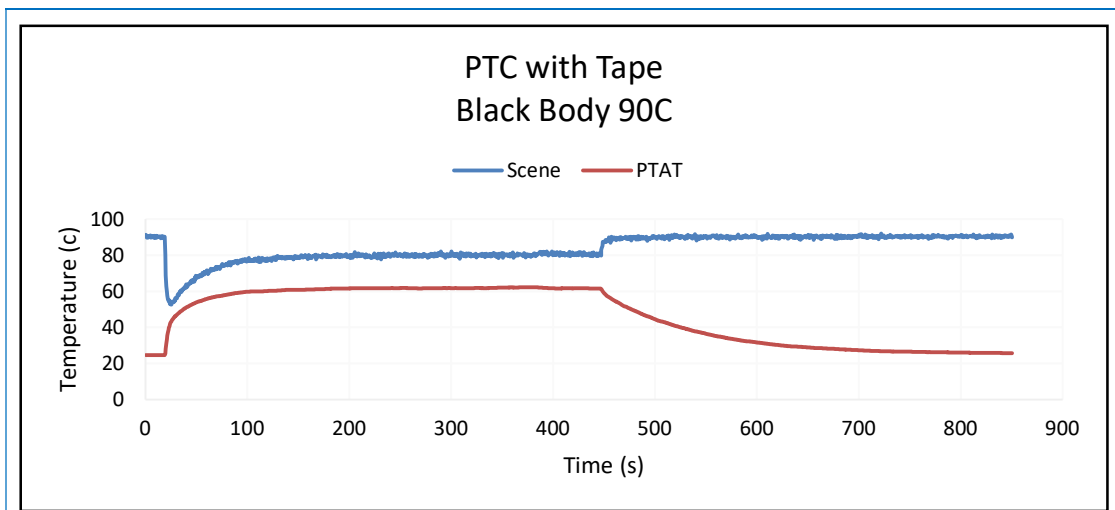


Fig. 2. Graph for sensor on PTAT heat up by heat source.

2.2 Techniques can be employed to reduce the influence of heat sources on sensors

2.2.1 Strategic Placement

Increased Distance from Heat Sources: The simplest and most effective way to reduce the sensor's exposure to a heat source is to increase the physical distance between the sensor and the heat-generating equipment. The farther the sensor is from the heat source, the less likely it is to pick up heat-induced errors

To calculate heat transfer through the FR4 PCB material (conduction), the following formula is commonly used:

$$Q = \frac{k \cdot A \cdot \Delta T}{d}$$

(EQ.1)

Where:

- **Q** = Heat transferred (W, Watts)
- **k** = Thermal conductivity of the material (W/m·K) (for FR4, it's typically around 0.3 W/m·K)
- **A** = Cross-sectional area through which heat is conducted (m²)
- **ΔT** = Temperature difference across the material (K or °C)
- **d** = Thickness of the material (m)

Key Factors:

Thermal Conductivity (k): The rate at which heat is conducted through the material. For FR4, this value can vary slightly depending on the specific type, but it's approximately 0.3 W/m·K.

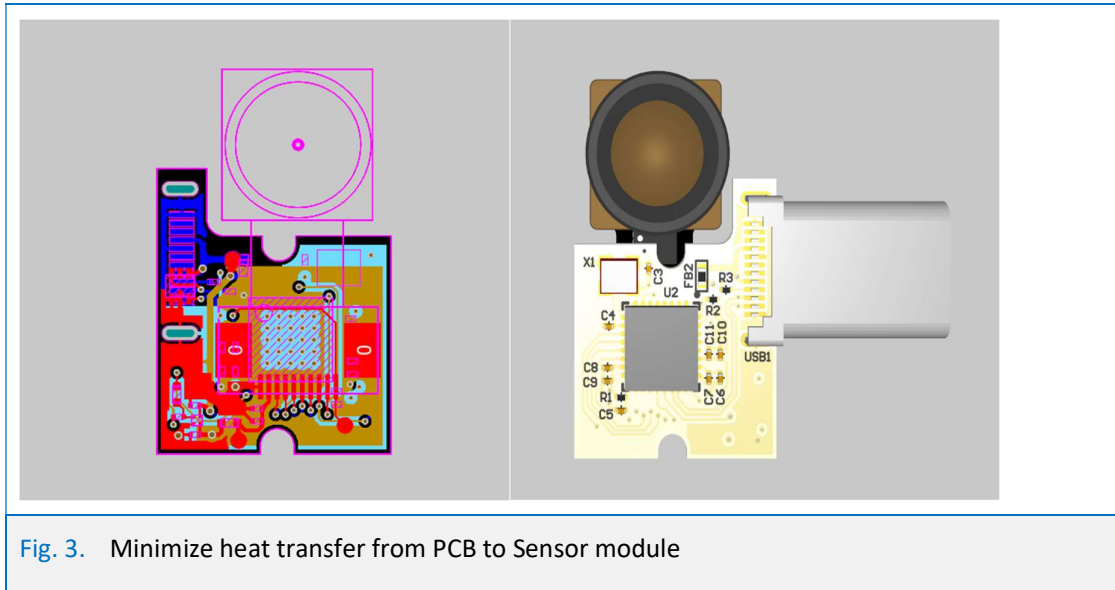
Thickness (d): The thickness of the PCB affects how easily heat can move through it. The thicker the PCB, the higher the resistance to heat flow.

Cross-sectional Area (A): This would be the area through which heat is being transferred. For a PCB, you would consider the area of the board in contact with heat sources.

Temperature Difference (ΔT): The difference between the hot spot (usually the source of heat) and the ambient temperature or the cooler side of the PCB.

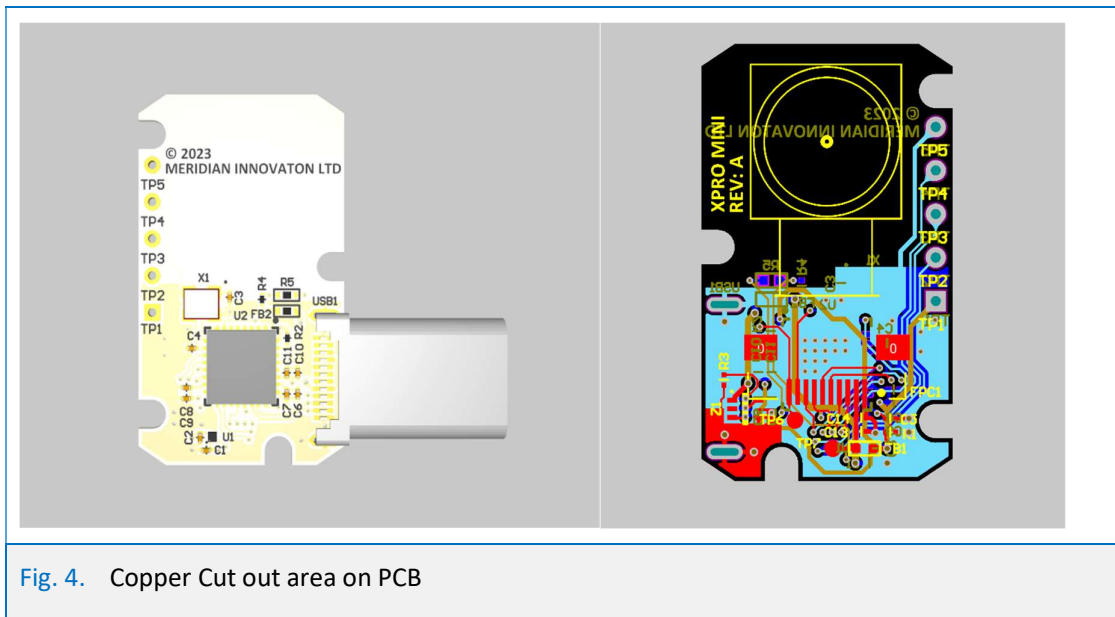
2.2.2 Physical Separation

Avoid placing the sensor module directly on the PCB surface. Ensure proper thermal isolation between the sensor module and the PCB



2.2.3 Thermal Isolation with Copper Planes

Sensor module should be isolated from dedicated copper planes or ground layers, if sensor module placed on PCB, These planes help distribute heat across the PCB, creating copper cut out will minimize heat transfer to the sensor module if sensor module placed on PCB surface.



2.2.4 Insulator between camera module and PCB

Using a simple insulator such as Paper/Felt/Foam to reduce heat transfer between the heat source and the module, the initial temperature drop can be significantly reduced or eliminated altogether. However, there may still be a steady-state error caused by the temperature gradient.

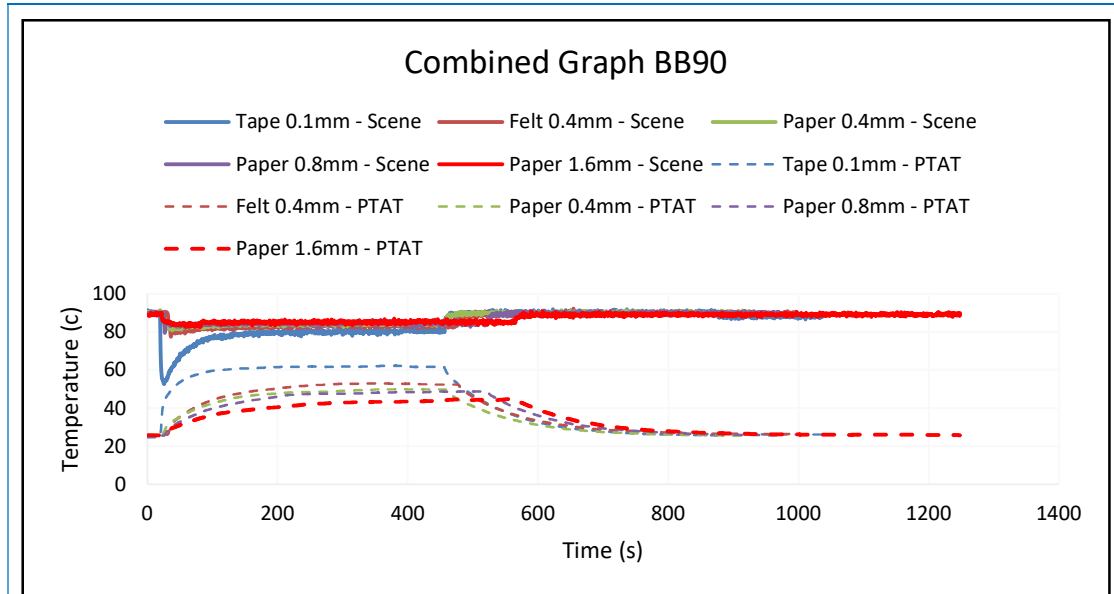


Fig. 5. The initial temperature drop upon contact with the PTC is significantly reduced by using an insulator. Without an insulator, the drop is around -35°C, but with an insulator, it reduces to -10°C.

The steady-state error improves as more insulating material is used. With insulator thicknesses of 0.4mm or greater, the error is reduced to 4-5°C

2.3 Module in Enclosure

2.3.1 Heat transfer from Housing/Casing Holder

The primary mode of heat transfer occurs when there is direct physical contact between the housing and the sensor module. The housing or casing, typically made of metal or plastic, absorbs heat from the environment or internal components (such as electronics) and conducts it through its material. If the sensor module is thermally coupled to the casing—either directly or via thermal interface materials—heat will flow from the higher-temperature regions of the casing to the sensor module, which is typically at a lower temperature. This process can also occur in reverse: the casing may be colder due to the ambient environment, while the sensor could be hotter due to self-heating or external heat sources on the PCBA, creating a temperature gradient between the lens holder and the chip. The rate of heat transfer through conduction is influenced by the thermal conductivity of the materials involved and the temperature gradient between the casing and the sensor. The goal is to achieve an isothermal state between the chip temperature and the lens holder as Fig. 6

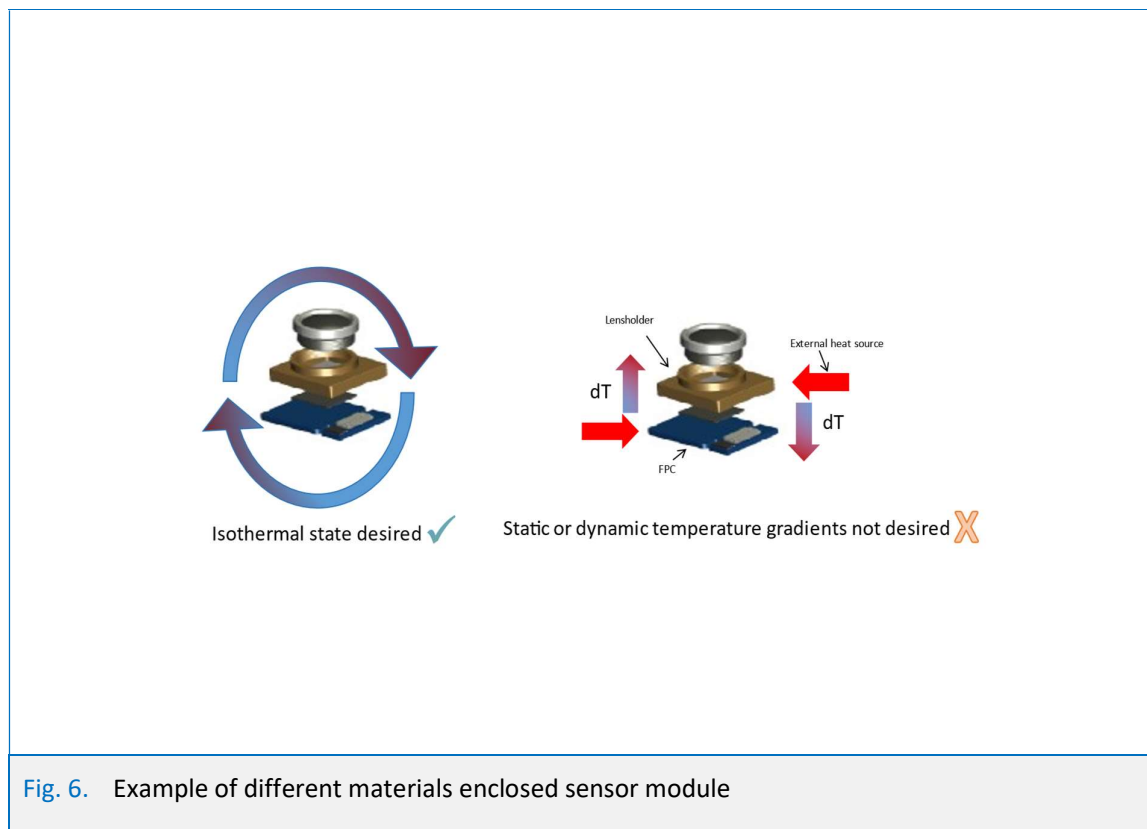
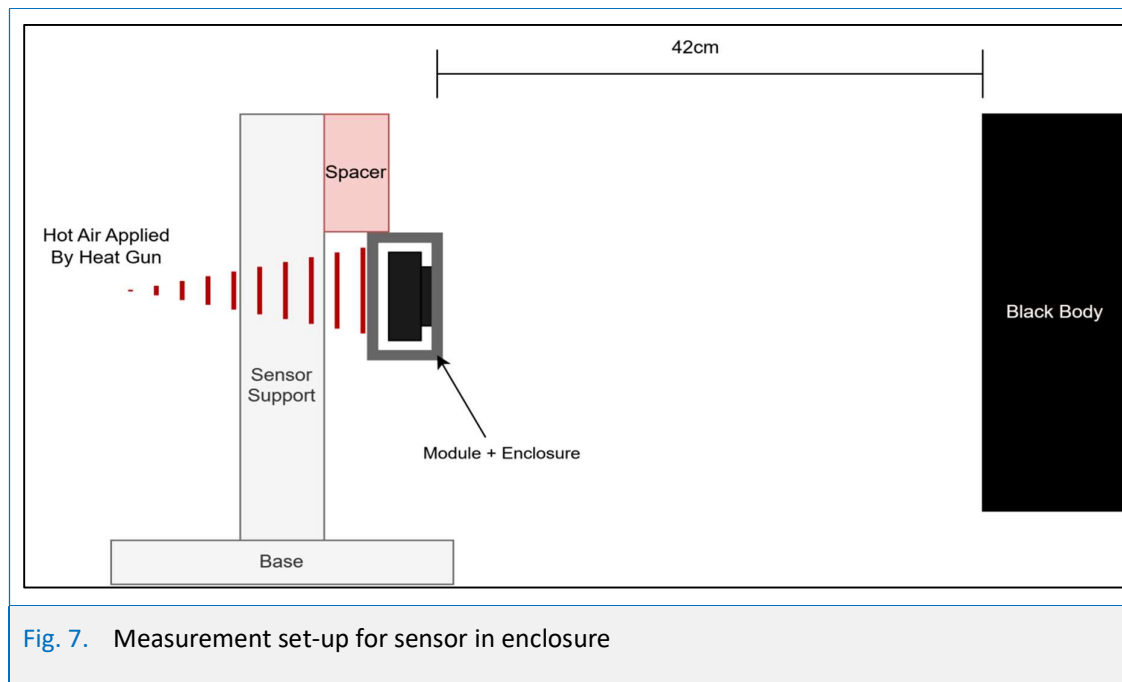


Fig. 6. Example of different materials enclosed sensor module

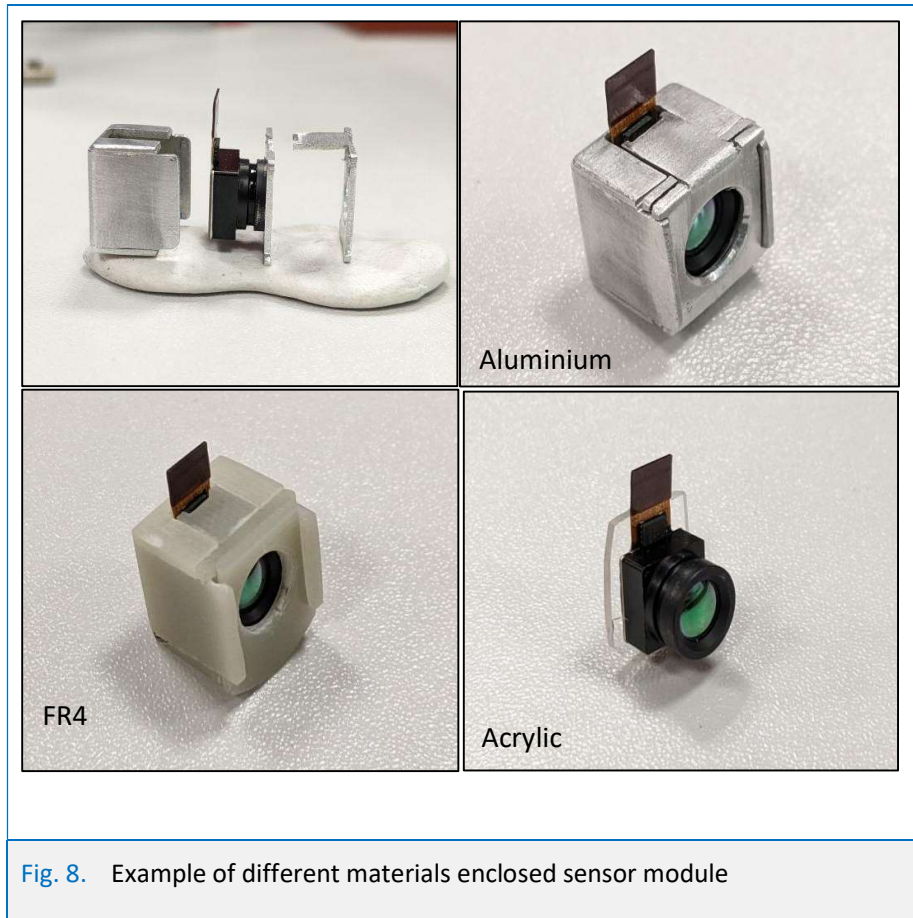
2.3.2 Set-up

To test the heat transfer from the casing or housing to a sensor module, a setup as shown in Fig. 6 is required to measure and analyze the thermal behavior.



2.3.3 Example of the module enclosure used

- Made of Aluminum sheet metal with a 1mm wall thickness.
 - There is a 1mm distance between the walls of the enclosure and the module.
 - Only the front of the lens holder is in direct contact with the enclosure.
 - An identical enclosure made out of PCB Material (FR4) was used as well.
 - Attach the acrylic to the base of the sensor module (simulating the direct interaction between acrylic and the sensor)
- * This is merely a simulation to represent a scenario where the module is enclosed within a housing, as it would be when integrated into a product.



2.3.4 Result for module in Aluminum enclosure

In both tests (220°C, 300°C Heat Gun Temperature), a noticeable difference can be observed compared to the test conducted with PTC/Air and without an enclosure

During the heat-up phase, there is a slight increase in scene temperature (with an overall error of less than 5°C) due to the lens holder acting as the main thermal path to the module.

During the cooling-down phase, a similar effect occurs as the enclosure cools down faster than the module creating a temperature gradient, resulting in a drop in scene temperature.

In both the heat-up and cool-down phases, the thermal gradient across the module is minimal compared to PTC with or without insulation. As a result, we observe a relatively small error, as the enclosure ensures more uniform temperature distribution.

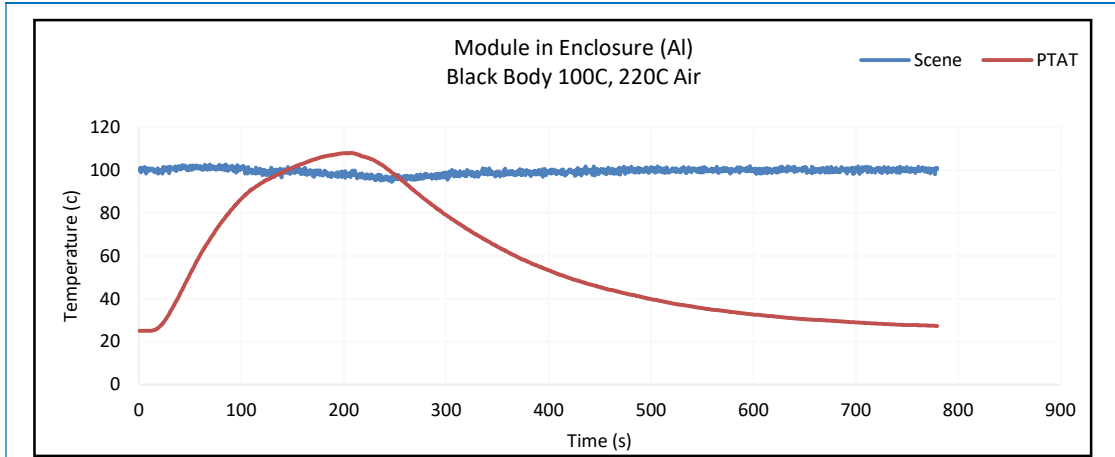


Fig. 9. Graph for sensor on PTAT heat up to 220 °C

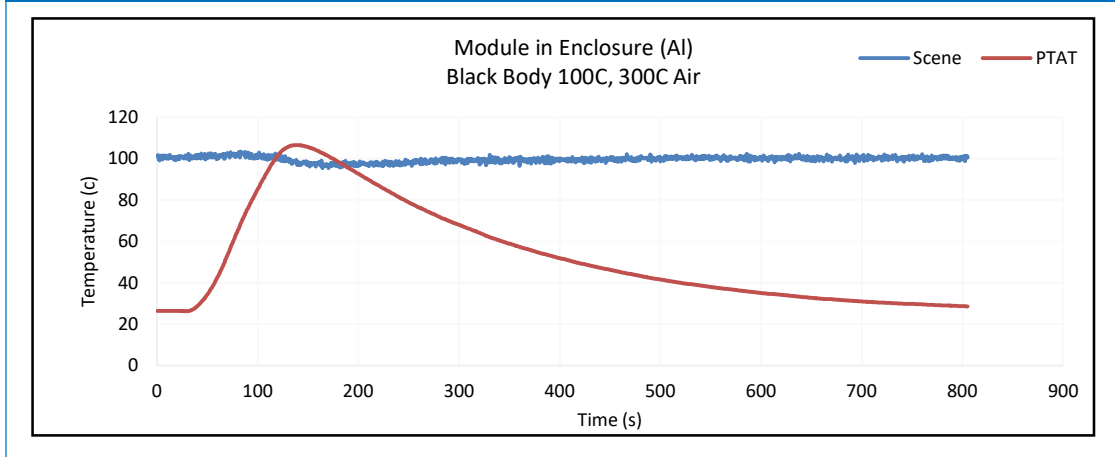


Fig. 10. Graph for sensor on PTAT heat up to 300 °C

2.3.5 Result for module in FR4 enclosure

With the use of an insulating material (FR4) for the enclosure or the Acrylic at the back of the module, the initial temperature drop no longer occurs.

However, a constant offset in scene temperature can be observed due to inadequate heat distribution when the enclosure is heated from behind. This causes the module to primarily heat up from the back rather than the lens holder, as seen in the previous enclosure (Aluminum).

Once the heat source is removed, the module rapidly recovers to the correct scene temperature as the enclosure stabilizes.

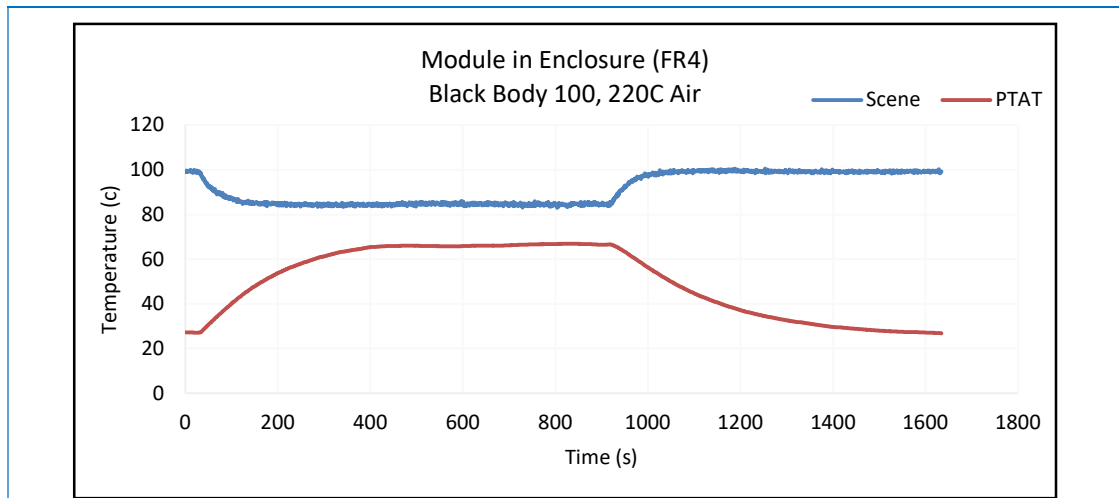


Fig. 11. Graph for sensor on PTAT heat up to 220 °C

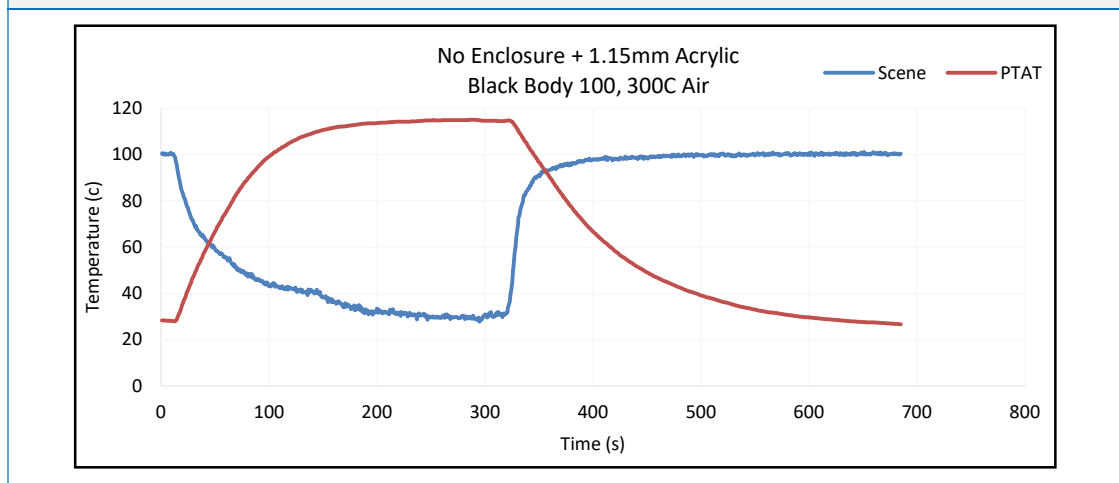


Fig. 12. Graph for sensor on PTAT heat up to 300 °C

3. SUMMARY AND CONCLUSION

3.1. Summary

By using a simple insulator such as Paper/Felt/Foam to reduce heat transfer between the heat source and the module, the initial temperature drop can be significantly reduced or eliminated altogether. However, there may still be a steady-state error caused by the temperature gradient.

Placing the module inside an enclosure/housing can significantly reduce the temperature gradient, thereby eliminating the initial temperature drop and resulting in a small steady-state error.

The location (side/back/bottom) of the heat application by the heat source (Heat Gun, PTC) on the enclosure (Al) had no noticeable effects between the tests (not shown here)

3.2. Conclusion

In PCB design, thermal management is a key consideration when dealing with both heat-generating components and sensor modules. By employing techniques such as strategic component placement, thermal isolation, the use of heat sinks and thermal vias, and considering the thermal properties of PCB materials, engineers can minimize the risk of heat transfer and ensure the longevity and reliability of the sensor module.

When a heat source is present inside the product, it is crucial to maintain as uniform a temperature as possible around the module housing or enclosure as to achieve this, it is advised to avoid direct contact between any heat source and the metal back plate of the module.

To prevent direct contact, introducing an air gap between the heat source and the metal back plate is recommended. Alternatively, using small contact points and incorporating insulating materials can further minimize heat transfer.

Using a housing made from a material with high thermal conductivity will result in more even heat distribution.

4. REVISION HISTORY

Revision	Date	Notes
0.0.1	Nov 2024	Initial Version

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6. CONTACTS INFORMATION

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