Layout Considerations for Wearable Temperature Sensing

Introduction

For wearable applications, such as fitness trackers and baby monitors, measuring skin temperature accurately can be challenging due to two major concerns: accuracy and speed.

Accuracy can be addressed by choosing a high-precision temperature sensor, as well as employing good PCB layout techniques.

A temperature sensor's thermal response is how fast the device responds to a sudden change in temperature. The speed of the response is determined by the amount of thermal mass—a material's ability to store heat energy—surrounding the sensor. By using good layout techniques, engineers can maintain a small thermal mass to improve the thermal response time.

PCB Layout Techniques

To accurately measure skin temperature, it is important to:

- follow good layout techniques
- understand the dominant thermal path
- isolate the sensor package
- place the device away from interfering heat sources

Another important technique is to minimize the temperature resistance between the measured surface and the temperature sensor—which can help decrease temperature response time—while also maximizing the thermal resistance from the PCB to the surrounding air—which can help reduce "leakage" from the sensor to the surrounding air. Employing these techniques will result in a faster response time and a more accurate temperature measurement.

Figure 1 shows the cross section of a TMP116 mounted on a PCB. The TMP116 measures temperature by measuring its own die temperature. The thermal bipolar junction transistor (BJT) within the die acts as the transducer. The transistor converts a thermal quantity into an electrical signal which is then measured and converted to temperature. The heat flows from the skin to the die through the via and exposed pad, which helps decrease thermal-resistance and provide the most direct heat flow path.

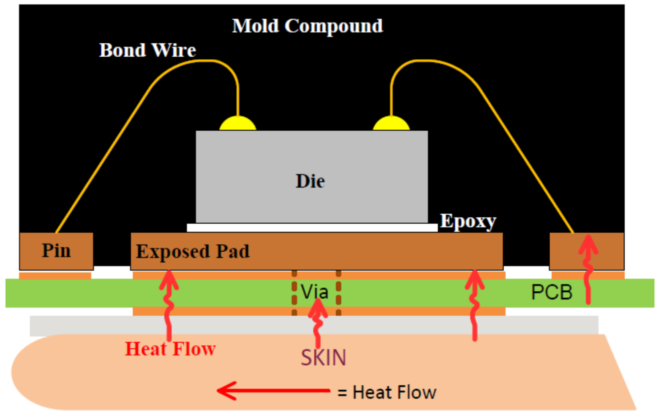

Figure 1. TMP116 Heat Flow Path

Placing the temperature sensor in a closed-ended stainless steel protective probe, as shown in Figure 2, may help prevent contamination or potential damage. This technique may be applied to wearable applications by placing the bottom of the PCB between the thermal-sensing contact and the skin.

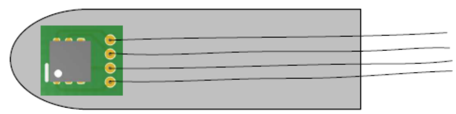

Figure 2. TMP116 Protective Temperature Probe

Another method is to control the thermal mass of the PCB. A thick PCB with a high thermal mass will respond to temperature fluctuations slower than a thin PCB with a lower thermal mass. TI advises to either use a thin PCB of 0.8mm thickness (rather than the standard 1.6 mm FR4 thickness), or use a flex PCB as shown in Figure 3 and Figure 4. These PCB designs will respond to changes in temperature more rapidly than a thicker PCB design with a high thermal mass.

Figure 3. Thin PCB Design

Figure 4. Flex PCB Design

The plot from Figure 5 shows the thermal responses from different PCB designs. The thin and flex PCB substrates have the fastest thermal response due to their small thermal mass.

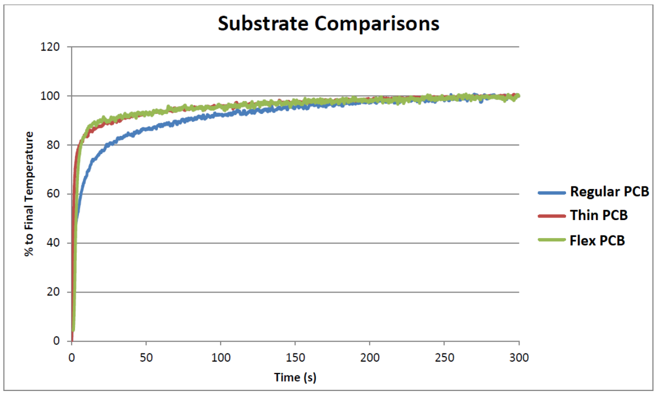

Figure 5. PCB Substrate Thermal Response Comparison

In addition to PCB layout, good mechanical and thermal contact is important to achieve a fast thermal response.

Thermal Response of Different Mediums

With wearable applications, it is important to choose a location to measure skin temperature that will result in a fast thermal response.

An experiment conducted using the TMP116 in a stainless steel probe investigates the thermal response time of the TMP116 to a sudden change in temperature using different mediums and contact locations, as shown in Figure 6. The stirred oil test is used as a reference for the other mediums because the test provides the fastest thermal response. The oral, underarm, and stirred oil experiments yield a faster thermal response time compared to moving air and still air.

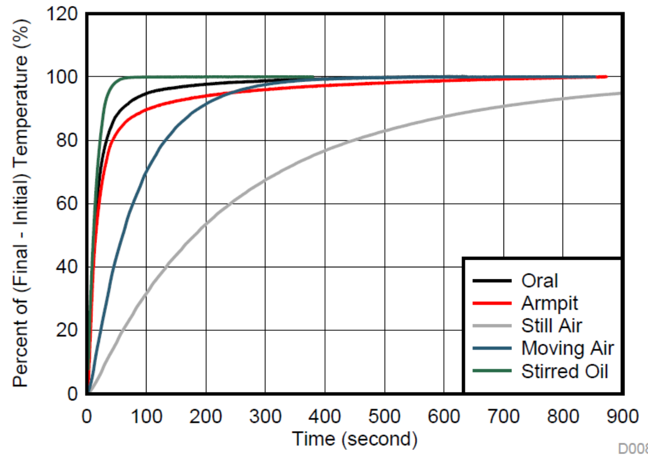

Figure 6. Thermal Response Comparison for Different Mediums

Device Recommendations

The TMP116 and TMP117 are digital temperature sensors designed for low-power, high-accuracy applications. Both devices provide a 16-bit temperature result with a resolution of 0.0078°C.

The TMP116 and TMP117 provide factory calibrated performances of ±0.2°C and ±0.1°C, respectively, across the human body temperature range, making these devices ideal for skin temperature measurements in wearable applications. The TMP117 sensor is designed to exceed ASTM E1112 requirements for electronic patient thermometers, making it an excellent choice for wearable health diagnostic applications. In addition, their compact 2.00-mm × 2.00-mm WSON packages have a unique thermal pad that aids in heat transfer from the skin to the temperature sensor.

To ensure optimal performance and device longevity, additional layout recommendations are discussed in the collateral in Table 1.

Table 1. Recommended Collateral

COLLATERAL	DESCRIPTION
Application Report	*Wearable Temperature Sensing Layout Considerations Optimized for Thermal Response*
Application Report	*Precise Temperature Measurements with TMP116*
Application Report	*Temperature Sensors: PCB Guidelines for Surface Mount Devices*