How to monitor board temperature

Introduction

Thermal issues in circuits could impact system performance and damage expensive components. Measuring the temperature of a PCB in sections where there are “Hot Spots” or “Power Hungry ICs” can help identify these issues to take preventive or corrective action in real time.

Systems designers may want to monitor the die temperature of a power hungry IC—such as a CPU, ASIC, FPGA, or DSP—to dynamically adjust its performance, or the designers may want to monitor “Hot” sections around power stages to either control the fan speed in a system or initiate a safe system shutdown.

The ultimate goal is to optimize performance and protect costly devices. Figure 1 shows a temperature-monitoring system on a high-performance computer board.

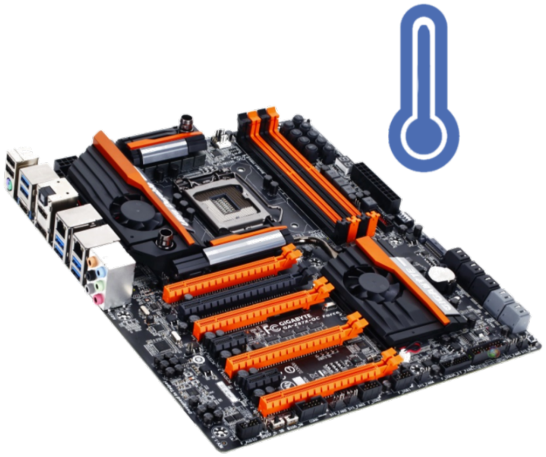

Figure 1. Temperature Monitoring on a Complex PCB

Heat Transfer From PCB to the Temp Sensor

Local temperature sensors measure their own die temperature to determine the temperature in a specific area. Therefore, it is important to understand the dominant temperature conduction paths between the die and the object or environment around the sensor. Heat is conducted primarily through two path types: through a Die-attach pad (DAP) attached to the package, or through the package lead pins.

The Die-attach pad (DAP), if present, provides the most dominant thermal path between the PCB and the die.

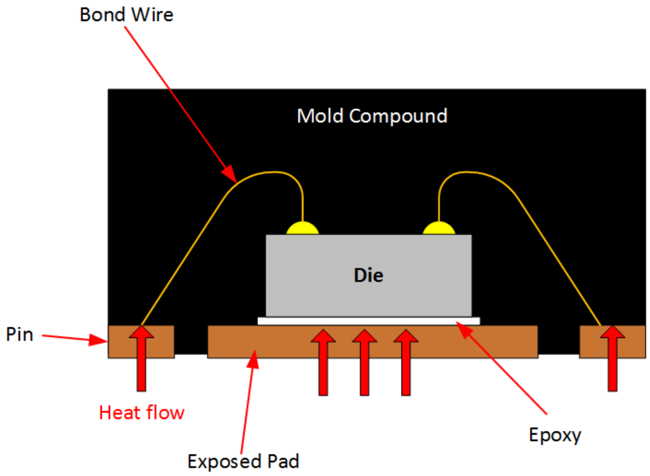

Figure 2. Package With DAP

The leads and pins provide the most significant thermal path if the package type does not include a DAP.

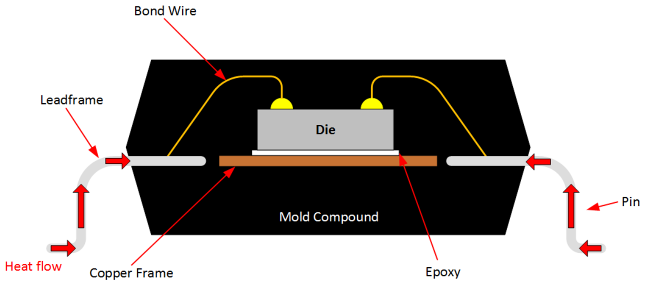

Figure 3. Package Without a DAP

The mold compound provides an additional thermal path, but due to its low thermal conductivity, any heat transfer through the mold compound itself is slower than the heat transfer through the leads or DAP.

Thermal Response

The package type choice determines how quickly the temperature sensor can respond to changes in temperature. Figure 4 shows the relative thermal response rates of different classes of selected SMT package types that are used for temperature measurements.

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Packages without a mold compound (CSP, DSBGA) and packages with a DAP (QFN, DFN) are designed for applications that require a fast thermal heat transfer from the PCB, while packages without a DAP are designed for applications that require slower response rates. A fast thermal response rate allows the temperature sensor to respond to any temperature changes quickly and therefore provide an accurate reading.

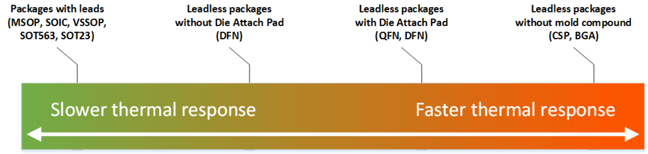

Figure 4. Thermal Response Chart

Design Guidelines - Bottom Side Mounting

The sensor location should be as close as possible to the heat source designers want to monitor. The designer should avoid perforations or slits in the PCB between the heat-generating IC and the temperature sensor, because they could reduce or stop the thermal response. If possible, mount the temperature monitor on the bottom side of the PCB directly below the heat source as shown in Figure 5.

TI recommends that designers use vias to transfer heat quickly from one side of the PCB to the other, because vias have a better thermal conductivity of copper compared to FR4. Therefore, a designer can use as many parallel vias or filled conductive vias as feasible to transfer heat from the heat source to the temperature monitor to create a fast thermal equilibrium between the two ICs. A QFN or DFN package with a DAP can further help decrease the thermal resistance path between the vias and the sensor die.

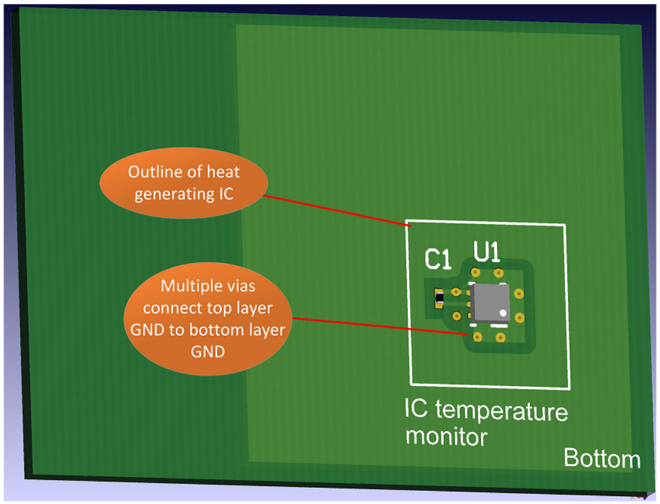

Figure 5. Sensor Mounted on Opposite Side of Heat Source

Design Guidelines - Ground Plane Considerations

If it is not practical or cost-effective to place the temperature sensor on the opposite side of the heat source. Place it on the same side as close to the heat source as possible as shown in Figure 6.

The most effective way to create thermal equilibrium between the heat source and the temperature monitor is through the use of a ground plane. Use a solid ground plane that extends from the heat source to the temperature sensor.

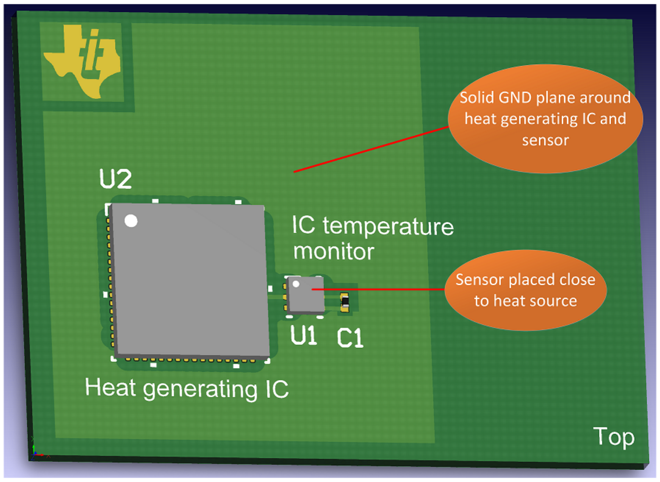

Figure 6. Shared GND Plane Helps With Thermal Equilibrium

Summary

Temperature monitoring is critical in PCB design that has “hot” power sections or “power hungry” ICs. The systems designer must evaluate whether the selection of local temperature sensors will meet the system requirements and protection schemes of their design.

The designers must consider the sensor location and the high thermal conductivity path to create a fast thermal equilibrium between the sensor and heat-generating element.

This tech note discusses the basics for package selection and sensor placement in the board and layout. More critical PCB and layout guidelines are covered in the *Temperature Sensors: PCB Guidelines for Surface Mount Devices* application report (SNOA967).

Table 1. Related Documentation

COLLATERAL	DESCRIPTION
Application Report	*Temperature Sensors: PCB Guidelines for Surface Mount Devices*
Application Report	*Ambient Temperature Measurement Layout Considerations*

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