RETHINKING THERMAL DESIGN

Utilizing Your Thermal Budget to Your Best Advantage

Temperature is a major design constraint for any system that generates heat, including automotive, aerospace, telecom, industrial, and lighting applications. Even a system that is 90% efficient still has to dissipate 10% of its power as heat. Excessive heat can substantially reduce the operating life of lithium batteries and LEDs, and thermal runaway can require a system to be powered down or even cause it to fail.

A common approach to managing heat is through active cooling. The heat is transferred through the air in the system and mechanical measures such as fans dissipate the heat. Fans, however, generate noise, consume power, increase cost, and lower reliability. Passive thermal management reduces heat by conducting it out of the system, typically by spreading it over part of a metal enclosure. Effective passive thermal management can eliminate the need for active cooling (see Figure 1).

Too often, thermal management is left as a design-for-manufacturing consideration. The electrical design team's primary focus is on functionality. They make sure the processor has enough performance

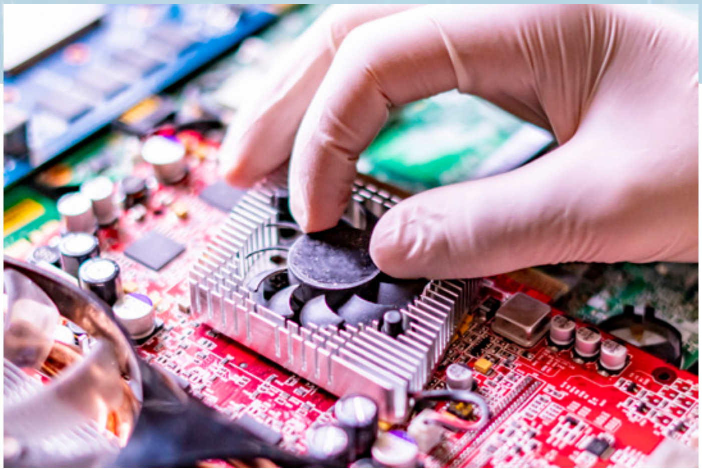
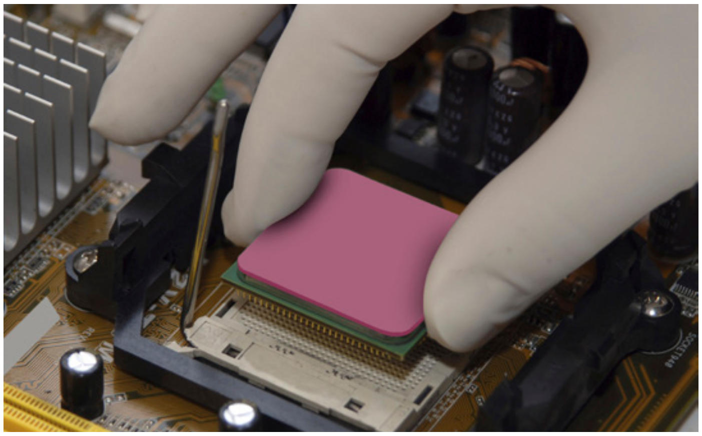


FIGURE 1. Fan-based cooling (above): Active cooling requires mechanical measures to dissipate heat, such as fans that generate noise, increase cost, and lower reliability.; (below) pad-based thermal conduction.

Pad-based thermal conduction (below): Passive thermal management reduces heat by conducting it out of the system, typically by spreading it over part of a metal enclosure. Effective passive thermal management eliminates the need for active cooling.



and sufficient memory to meet real-time application requirements. With the current emphasis on small form factor and energy efficiency, size and power are part of their considerations. The design is then passed to the PCB designer, who lays out the board and takes into account issues like signal integrity, noise, and EMI.

Once the PCB is done, this "finished" design is passed to the mechanical engineer whose job it is to fit the board into a physical enclosure. In many designs, this is the first time that thermal management is seriously considered. With tight space constraints, time-to-market pressures, and limited budget remaining, mechanical engineers can find themselves with a real challenge to overcome.

THE THERMAL MANAGEMENT CHALLENGE

There are many factors that make transferring heat out of a system difficult to implement effectively:

- **Electrical isolation:** A metal enclosure can transfer heat out of a system only if there is an electrically conductive material to bridge the gap between the heat source and the enclosure.
- **Uniformity:** Thermal conductivity depends upon how uniformly the heat source is connected to the conductive material. It's important for thermal materials to offer a selection of thicknesses to ensure there will be good contact when stack up tolerance is taken into consideration (see Figure 2).
- **Compressibility:** There may not be enough space in the enclosure when the door is closed or between subsystems to fit certain types of conductive materials. Thermal management, in this case, requires some level of compressible material to accommodate space constraints.
- **Ease of assembly:** Thermal materials that require manual installation increase assembly complexity and cost while introducing potential reliability issues. Ideally, thermal materials need to be implemented by automated assembly systems. An important factor to consider for automated systems is how to apply thermal materials without making a mess, such as preventing a dispensed grease from spreading into other parts of the system.
- **Cost:** Difficult thermal challenges limit options, increasing the cost to address them. Cost is even more of an issue when the electrical design team has utilized the majority of the monetary budget and made choices that make managing heat transfer more challenging.

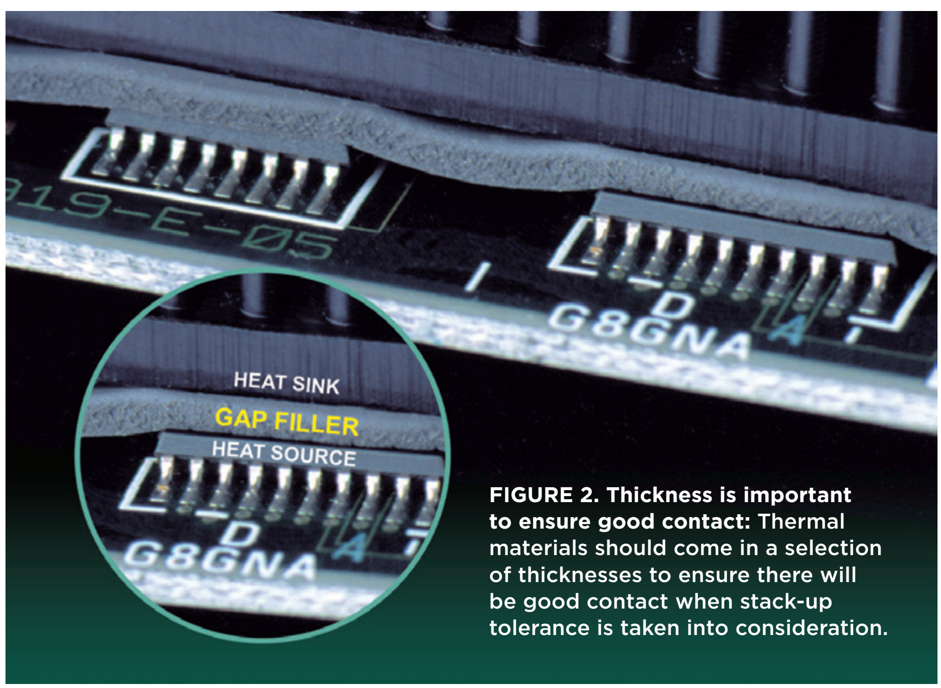


FIGURE 2. Thickness is important to ensure good contact: Thermal materials should come in a selection of thicknesses to ensure there will be good contact when stack-up tolerance is taken into consideration.

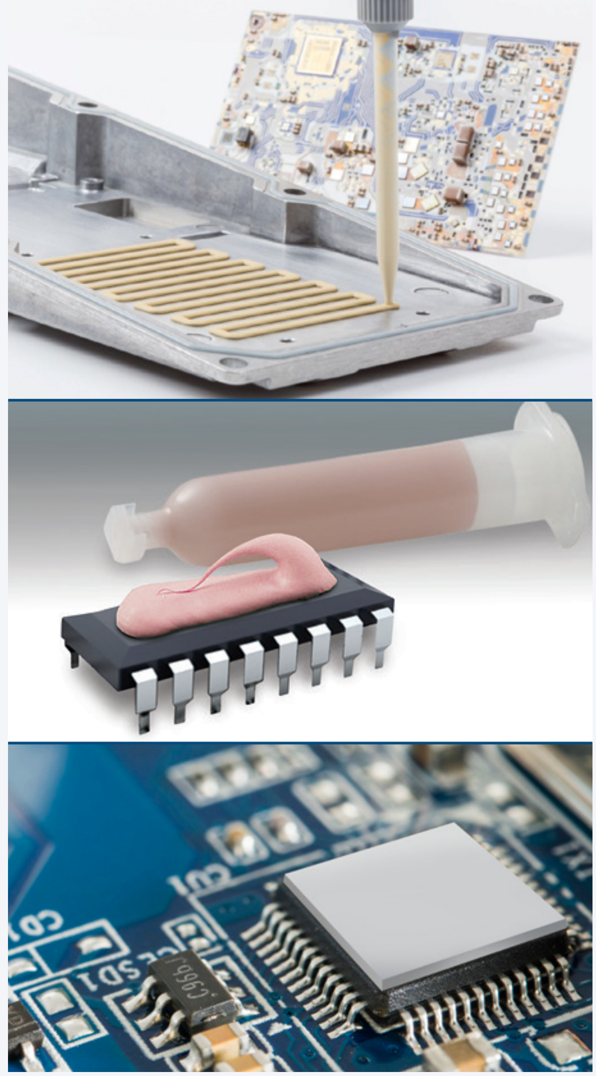


FIGURE 3. Different types of thermal materials: Thermal materials include gap filler pads, putty type gap fillers, two-part cure-in-place gel, non-curing form-in-place gel, thin-film materials, and greases. Each offers different advantages and tradeoffs.

DESIGNING WITH A THERMAL BUDGET IN MIND

There are several budgets that engineers track during the various design phases: cost, signal integrity, noise, power. By acknowledging these constraints earlier in the design process, engineers are able to make decisions that conserve or expend budget as a tradeoff for some other benefit. For example, selecting a higher-performance receiver relaxes RF-signaling layout constraints. Alternatively, more rigorous layout allows a lower-cost receiver to be used.

Electrical design teams take price, performance, power, time to market, ease of use, and many other factors into account when selecting components and developing a system architecture. When thermal management is not considered early in the design process, this means that engineers have little awareness of the impact their choices have for the mechanical design team. Optimizing their choices without taking thermal issues into account can create time-consuming and expensive temperature management problems later that ultimately delay product time to market, add to assembly complexity, increase system cost, and negatively impact reliability.

The key to managing heat optimally is understanding the available options. Thermal management involves much more than thermal grease, heat sinks, and fans. Just like a noise or power budget, a thermal budget can be used to choose between different tradeoffs — cost versus performance versus assembly complexity versus ease of use, and so on. There is significant investment and innovation in thermal management technology, just like other areas of electronics. For some engineers, the breadth of options available are surprising. And with these options, engineers can choose the tradeoffs that best meet their application and market requirements.

For example, Fujipoly, a leader in thermal technology and innovation, has a wide portfolio of thermal technologies including gap filler pads, putty type gap fillers, two-part cure-in-place gel, non-curing form-in-place gel, thin-film materials, and greases, to name some (see Figure 3). These materials range from general-purpose to high-performance, and many components meet IETF, ISO, and automotive certifications. Each material offers different advantages and tradeoffs. Grease compounds, while messy, are a low-cost option that provides good performance. Pads provide high performance, and putties are useful where compressibility is important.

Many of these materials work well with automated assembly systems. Fujipoly has developed thermal pads that can be used by robots and pick-and-place machines by overcoming issues with pads being soft, tacky, and having a carrier film that needs to be removed. Continuing research with integration partners is being done to transform other by-hand solutions into materials that work well in automated settings. Fujipoly also leads innovation in next-generation thermal technology with advances like thermal pads that provide additional EMI absorption for applications that need it.

Sample kits available on **fujipoly.com**.

Fujipoly has extensive experience with thermal management and can help engineers select the optimal technology and implementation for their application. For example, larger pads appear to be the best choice for ease of use. However, Fujipoly can provide pads die cut in a number of custom shapes directly to manufacturers. Such custom pads are optimized for the job they need to accomplish, providing the right amount of compression and more effective heat transfer at a lower cost.

An important aspect of Fujipoly's thermal offerings is expert technical support. Applications engineers are available to help with overall thermal design. Beyond selecting the right materials, they can help with size and shape optimization, as well as assembly considerations and thermal testing. There is also a quick turnaround for samples to help engineers meet tight deadlines.

Thermal design is an essential part of designing reliable electronics systems. By considering thermal issues earlier in the design cycle, design teams can avoid creating major problems for mechanical engineers when time is short and money is tight. However, with an understanding of the many thermal materials and options available, mechanical engineers have the flexibility to make optimal tradeoffs and address even the most challenging thermal issues on time and within budget.