SOLUTIONS ENGINEERING
Thermal Management

New Materials and Techniques Tackle PCB Thermal Management

Chipmakers do their part. But at the printed circuit board level, using the right mix of old and new materials effectively ushers out increasing heat.

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New thermal management materials and techniques are being applied to subsystem PCB designs to meet heat dissipation demands introduced by new generations of mostly analog and some digital ICs that dissipate high current and high power. Thermal management focuses on effectively dissipating heat generated by those high-power designs, on high thermal conductivity, and on maintaining low coefficients of thermal expansion (CTE), while managing CTE mismatches between components, their interconnects and the PCB.

Chipmakers use a variety of packaging such as plastic, ceramic, flip chip, leadless chip carrier (LCC) and wafer-level packages (WLP). Each has a lower CTE than a standard PCB. Consequently, a CTE mismatch occurs between device packaging and the PCB. Depending on the application and associated cost budgets, PCB designers, hardware engineers and PCB fabricators implement a variety of different materials and techniques to deal with those CTE mismatches and manage thermal issues.

While chipmakers are doing their part to improve thermal management for their devices, EMS providers are placing special attention on thermal management issues at the PCB design level. In these instances, remedies range from using applicable board materials to paying special attention to mounting holes. In between, there are several new as well as tried-and-proven materials and methods to improve thermal conductivity and heat dissipation.

The industry continues to patent new inventions and offers a variety of new thermal management materials and techniques. There are too many to cover here. However, those discussed here are prominent ones in the tool kit of seasoned PCB designers and engineers. They include advanced thermal modeling software, new heat sink material, new in-plane high conductivity carbon composite material, special casing material and edge plating. Proven techniques include copper thieving, increasing trace thickness, and ultimately, exploiting even the mounting holes to dissipate heat.

Thermal Modeling

New advances are being made to PCB thermal modeling and performance prediction software to give hardware engineers and designers a head start on managing thermal issues. It's an invaluable tool to the PCB designer to assist him or her to quickly and easily understand the relationships between components and how their placement affects a PCB's thermal dynamics.

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Thermal modeling is used at the most basic levels of board layout, mapping, for investigating system airflow, heat sink design and other cooling mechanisms. With this tool, PCB designers can extend computer-aided design into prototyping and testing, thus saving considerable time and expense. Also, designers can build a virtual prototype of the system and test the airflow and heat distribution at both the board and the system level.

Equally importantly, thermal modeling gives the PCB designer the critical tool for conducting thermal fatigue failure analysis. In turn, these analyses can be modeled to provide failure prediction models. While board failures may not occur for a period of time, prediction models can forecast when certain PCB materials will incur thermal fatigue and cause field failures.

Heat Sinks

Heat sinks have historically been the PCB workhorse for thermal management. They help keep devices at temperatures below their specified maximum operating temperature. There are many versions, different designs and various ways of optimizing heat sinks. Over time, the technology has progressed with the use of new materials. For example, carbon fiber and boron nitride are recent materials applied to heat sinks. High thermal conductivity fiber spreads heat well at 800 watt per meter Kelvin (W/m-K) in the direction of the fiber. However, at 0.5 W/m-K, it doesn't spread heat up and down very well.

Developers have applied boron nitride crystals as a way to efficiently move heat from one fiber ply to the next. These crystals are used to "salt" carbon fiber sheets or prepregs. Two or more sheets are then laminated together to form the heat sink material, and throughput for up-down directions has been improved from 0.5 to about 4 W/m-K.

Due to their high cost, however, these materials will likely find limited use in future PCB fabrication and may not replace aluminum heat sinks in many applications. Still, carbon fiber heat sinks may best be used in systems that don't use air-cooling. These may include aircraft, missile and spacecraft components, automobiles, high-end computers and medical equipment.

On the other hand, fin-based aluminum or copper heat sinks find greater acceptance in many applications due to their low cost and ideal thermal dissipation characteristics (Figure 1). Aluminum has a highly acceptable 205 W/m-K thermal conductivity, while copper is about twice as high at about 400 W/m-K. Aluminum heat sinks are inexpensive; copper ones cost more and they weigh more. Consequently, aluminum gets the nod for most cost-effective applications, and copper is used in selected ones where cost isn't an issue.

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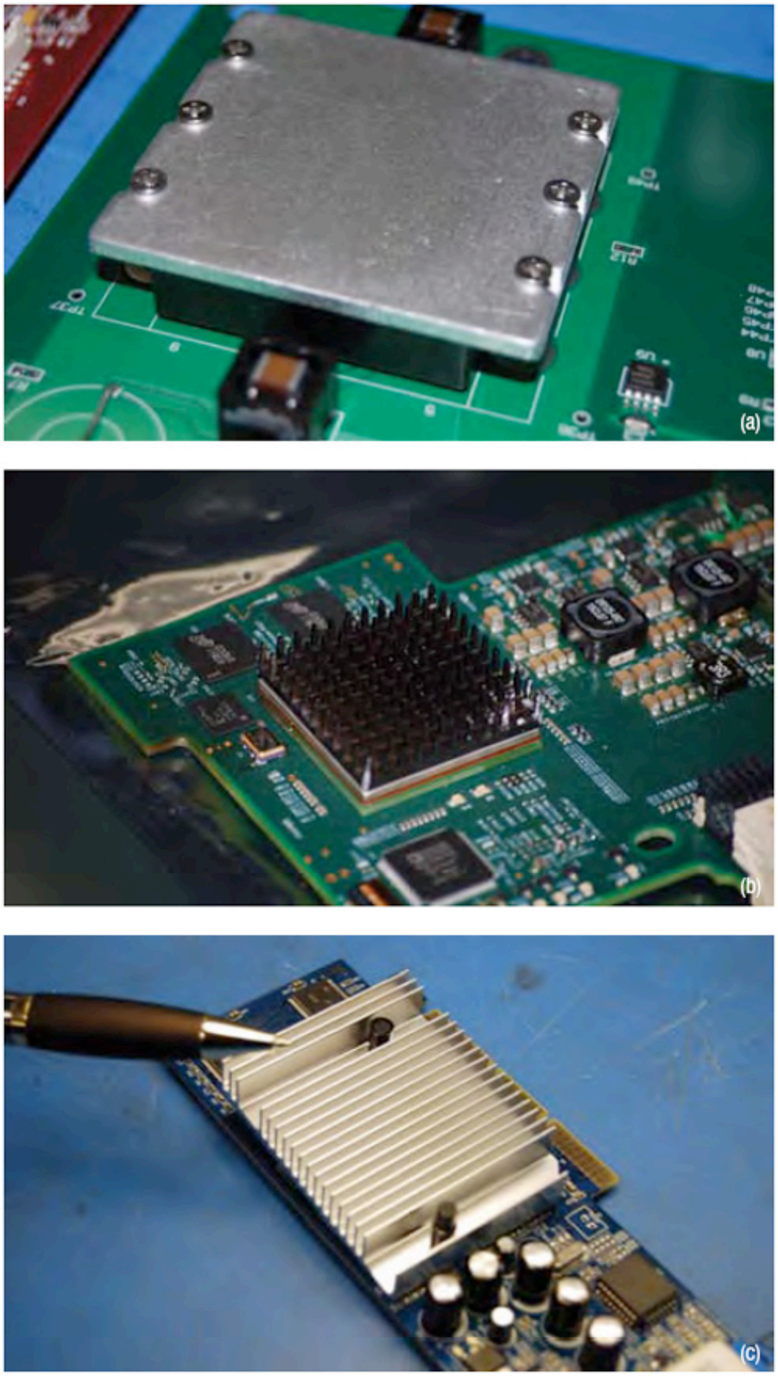

Figure 1 Several varieties of heat sink: (a) 2"x2" aluminum flat heat sink for analog and digital applications, (b) omni-directional low profile heat sink, suited for limited space applications and (c) 2"x2.5" fin-based heat sink for high powered analog circuits.

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