

Thermal Management Tools Face Cooling Issues

From software simulation packages to better thermal interface materials, heatsinks and exotic forms of heat management, increasing power dissipation levels of shrinking IC devices are challenging electronic circuit and package designs.

ICs AND THE PACKAGES that house them continue to shrink. In the meantime, they are operating at higher frequencies and offering higher-performance levels while generating more power — much of it in the form of heat. As a result, this is dramatically raising the challenge of thermal management for electronic devices, subsystems and systems.

The latest forecast by the International Technology Roadmap for Semiconductors reveals the challenges that lie ahead. Internal dimensions for logic ICs will drop from 25 nm in 2007 to 6 nm in 2013 while their functional densities will multiply several times within the same time frame, going from 1106 million transistors to 4424 million transistors for microprocessors.

All of this will require the most innovative methods for dealing with heat. Just look at the latest GHz-clock-rate microprocessors with their state-of-the-art cooling techniques to see why heat management presents such a huge challenge.

Heat management is difficult in the design of low-profile and small-footprint dc-dc converter power supplies. Many of these make use of high-power devices such as field-effect transistors (FETs), insulated-gate bipolar transistors (IGBTs), power controllers, motor drivers and high-frequency logic ICs.

However, many tools are available for tackling heat-management challenges, including simulation software, sensing techniques and methodologies, heat-control architectures, and various materials — which all can go a long way in solving thermal management problems. Heatsinks, thermal interface materials (TIMs), thermal vias and active cooling systems are being implemented to solve modern heat-management issues.

A SYSTEM-LEVEL APPROACH

Designing a cost-competitive power supply requires careful consideration of the thermal domain that supply operates in, not just the electrical domain. Although there are many thermal plots and data for semiconductor ICs, how they fit into a system and the resultant thermal influence is up to the designer. At a minimum, designers often are forced to carefully

evaluate device datasheet thermal specifications and characterizations, and choose one of many methods in which devices are rated. Knowing which one is the right one can prove tricky.

Generally, the thermal domain has been the mechanical engineer's field of knowledge while the electrical domain was left to the circuit designer. It is becoming increasingly necessary for an electrical engineer to have a better understanding of the thermal domain to optimize his or her design.

Choosing the right thermal simulation software has pros and cons that must be evaluated carefully. These include the cost of the software package, the amount of training involved, and maintenance and update fees. Performance-wise, it also includes simulation speed, the ability to model all forms of heat transfer (e.g., convection, radiation and fluid flow), the software's compatibility with devices such as heatsinks, heat pipes, enclosures and pc boards, and the ability to import files from other computer-aided design (CAD) packages.

How well the software satisfies a user's thermal simulation needs depends on the specific numerical method it uses for modeling specific tasks. Because heat management includes conduction, cooling and radiation methods, the software should be able to handle these tasks. Such products are known as computational fluid dynamics (CFD) software.

Some helpful CFD software programs include FloTHERM from the Mentor Graphics' Mechanical Analysis Division

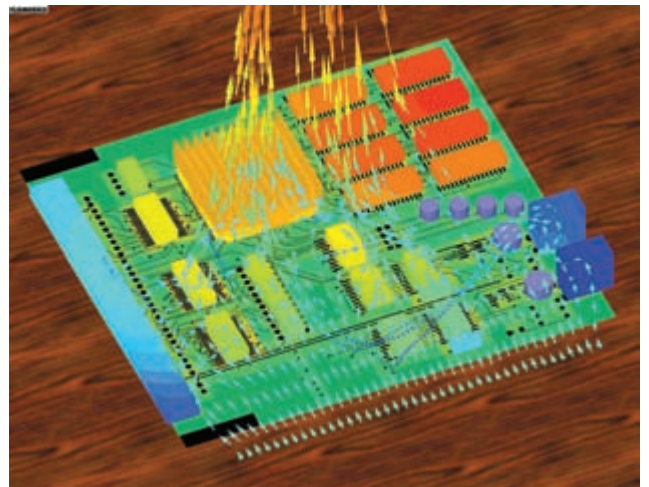


Fig. 1. Computational-fluid-dynamics- (CFD-) based thermal simulation software such as FloTHERM from Mentor Graphics Corp.'s Mechanical Analysis Division (formerly Flomerics Corp.) predicts airflow and temperature for both sides of a pc board.

(formerly Flomerics), and Fluent, Iceboard and Icepak from the Ansoft subsidiary of Ansys.

FloTHERM enables engineers to create virtual models of electronic equipment, perform thermal analysis and test design modifications in the early stages of the design process before any physical prototypes are built. Known as a “design class” tool, FloTHERM is industry-specific, allowing designers to choose the version that most suits their applications. For example, in the design of a pc board that might be used in a power supply or other piece of equipment, it predicts airflow and temperature for both sides of the board (Fig. 1).

Ansys also provides software packages. The company’s CFX software provides conjugate heat-transfer analysis. This capability features calculations of pure thermal conduction through solid materials coupled with calculations of the temperature in working cooling fluids. Ansys’ Fluent software provides a broad range of CFD physical modeling capabilities using a multi-physics approach. Furthermore, it has computational continuum mechanics (CCM) capabilities. Ansys’ Iceboard is targeted at thermal simulation of pc boards while Icepak is a fully interactive thermal modeling software suite for predicting airflow and heat transfer at the component, board and cabinet level.

Other simulation software packages include Rebecca-3D from Epsilon and WebTHERM from National Semiconductor. Epsilon’s Rebecca-3D is an electro-thermal analysis software package for improving reliability and determining the optimal thermal design of electronic assemblies. Because it uses boundary-element modeling, it can be used simultaneously for simulation and design analysis.

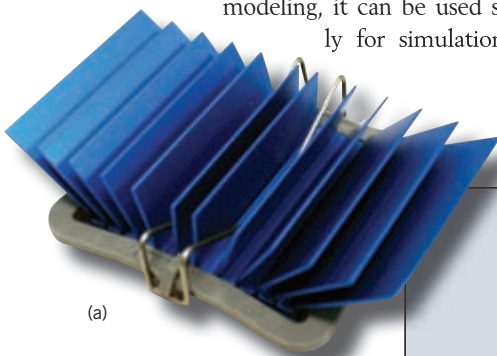


Fig. 3a. (above) Advanced Thermal Solutions’ maxiFLOW heatsinks use a maxiGRIP clip attachment design. They also feature a low-profile spread fin array design that maximizes surface area for more effective convection cooling.

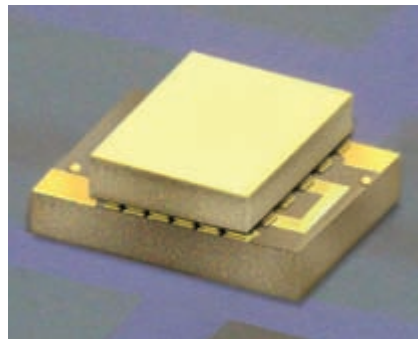


Fig. 2. This small footprint (2.8-mm²) thin-film-based thermoelectric cooler from Nextreme Thermal Solutions makes use of the company’s thermal copper pillar bump to pump out up to 1.5 W of heat. The HV14 can create a temperature differential of up to 51°C between its hot and cold sides.

National Semiconductor’s WebTHERM is an online tool that simulates the behavior of pc boards populated with components. It works with the company’s WebBench, an on-line software suite for circuit design.

BETTER MATERIALS AND METHODS

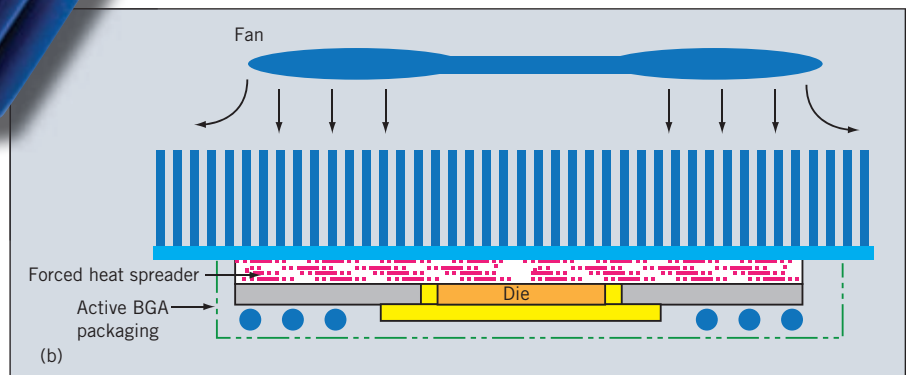
A crucial element in thermal management is the use of the proper TIM. Advances in materials technologies — whether solid, liquid or gel — are making important contributions to thermal management in electronic systems. Such materials generally are used between the component(s) they are trying to cool and the cooling element itself, reducing the interfacial resistance between, for

example, heatsinks and components.

Nextreme Thermal Solutions has been an innovator in developing thin-film materials for heat management. Its most recent product, the OptoCooler HV14, is a thermoelectric cooler module that can pump up to 1.5 W of heat and operates at a maximum voltage of 2.7 and a peak current of about 1 A within a footprint of 2.8 mm² (Fig. 2). It can create a temperature differential (ΔT) of up to 51°C between its hot and cold sides, making it suitable for the cooling and temperature control of optoelectronic devices. At the core of the module is Nextreme’s thermal copper pillar bump, which acts as a solid-state heat pump to add functionality locally on the surface of a chip or other electrical component.

Nextreme’s technology recently was demonstrated by an Intel-led team that included researchers from Arizona State University and RTI International. The team demonstrated that a small thermoelectric prototype device, such as the one made by Nextreme, embedded in a chip package could cool a much larger chip. The thermoelectric cooler they used cooled a 0.162-mm hot spot on a 140-mm² chip by nearly

Fig. 3b. (below) The company’s novel concept of a forced thermal spreader for BGA package cooling minimizes spreading resistance and thus improves heat flow.



15°C. This proved that nano-scale layers of thermoelectric material make for more efficient cooling devices, and that using such heat pumps for cooling some parts of microprocessors is a more energy-efficient approach than trying to cool the whole chip.

To illustrate the importance of the TIM in heat management, Kaveh Azar, president and of CEO of Advanced Thermal Solutions, studied a novel method of heat management for future microprocessors to minimize the junction temperature of a high-power device. He used a thin-film thermoelectric cooler embedded on the backside of the die. A micro-channel cold plate was used to transport thermal energy. Initial studies have shown that with “perfect” contact at different interfaces, a temperature reduction of 15°C can be achieved. However, when contact resistance and the thermoelectric cooler’s performance were taken into account, improvements dropped to only a few degrees of temperature. This demonstrates that thermal contact resistance plays a dominant mitigating role in heat management.

IMPROVEMENTS IN HEATSINKS

Heatsinks are a fundamental part of almost any heat management strategy, and Advanced Thermal Solutions is a leader in producing them as well as TIMs for heat management. Its maxiFLOW heatsinks with maxiGrip clip attachments provide low-profile heatsinking for ball-grid array (BGA) packages (Fig. 3a). They feature base dimensions of 27 mm × 27 mm × 14.5 mm and can flare out to 48.3 mm. The company also offers forced thermal spreaders for BGA packages (Fig. 3b).

According to Guy Dagan, marketing manager at Cool Innovations, there is a demand for large copper heatsinks, rapid convection cooling and heatsinks with low profiles. He says that today’s cutting-edge devices dissipate very large heat loads that require more cooling power, a larger surface area and thus larger heatsinks. The advent of smaller devices does not suit them well for aluminum heatsinks, which cannot spread the heat rapidly. “Due to limitations in copper forging technology, large copper fin heatsinks cannot be manufactured cost effectively” he adds.

The firm has developed a hybrid copper/aluminum pin fin heatsink that is an alternative for applications requiring large low-profile heatsinks (Fig. 4a). The 1.5-in.-high unit is available in various sizes with footprints as large as 8.2 in. ×

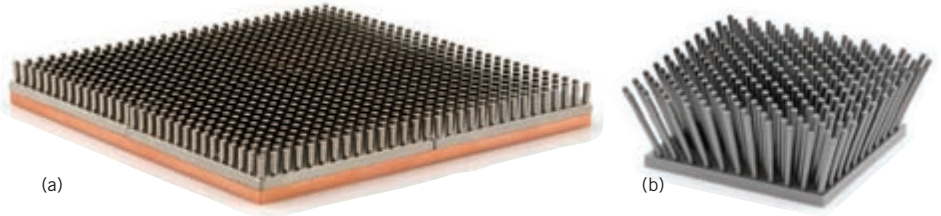


Fig. 4a. This hybrid copper/aluminum pin fin convection cooling heatsink from Cool Innovations provides an innovative means of cooling for applications requiring large low-profile heatsinks.

Fig. 4b. Cool Innovations also offers a flared-pin fin heatsink that can outperform traditional heatsinks by as much as 30% in applications that require natural convection cooling.

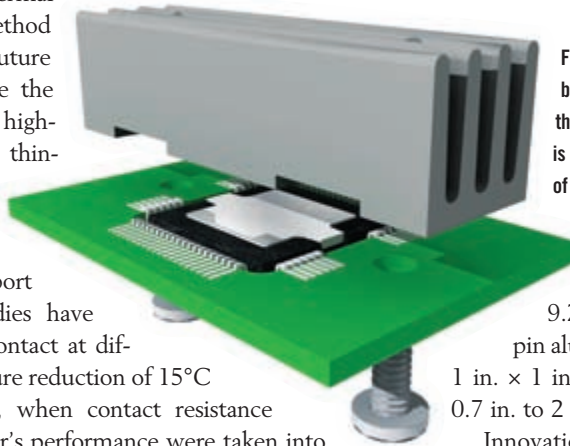


Fig. 5. A novel approach for heatsinking is employed by the Apex Precision Power team at Cirrus Logic for thermal management of motor-drive ICs. The package is mounted upside down on the pc board in the middle of a square pc-board cutout, and a standard heatsink is attached to the bottom of the motor-drive IC, which is located on the top side of the pc board.

9.2 in. Cool Innovations also supplies flared pin aluminum alloy heatsinks with dimensions of 1 in. × 1 in. to 5 in. × 5 in., in heights ranging from 0.7 in. to 2 in. (Fig. 4b).

Innovations in heatsink design and placement abound, as demonstrated by what the Apex Precision Power team at Cirrus Logic did for thermal management of its latest motor drive IC, the SA306-IHZ. The team designed the package to allow the user to mount the package upside down on the pc board, in the middle of a square pc board cutout (Fig. 5). Then, a standard heatsink is attached to the bottom of the motor-drive IC, which is on the top side of the pc board and is held down by a pair of screws.

The use of heat pipes for cooling is another way to manage thermal problems. Thermacore, a provider of heat-pipe cooling, produces advanced heat-pipe products as well as cold plates, heat exchangers, vapor-chamber cooling, plastic mold cooling and pumped-liquid cooling systems (Fig. 6). ☛

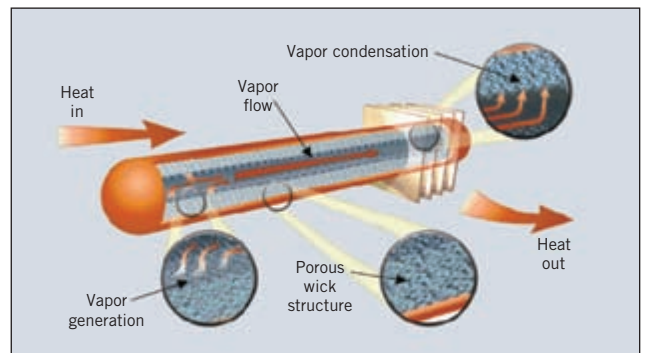


Fig. 6. This thermal heat-pipe cooling concept is a key strategy for a variety of Thermacore heatsinks for cooling power ICs.