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New Thermal Cooling Technology Addresses the Shrinking Electronics Issue

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The trend toward shrinking electronics both at the chip and board level have forced companies to crowd more functionality on their electronic systems into smaller spaces making the need to remove unwanted heat increasingly important. This trend is driving solution providers toward developing thermal interface materials (TIMs) to be much more application specific than in the past.

Over the last 25 years there have been revolutionary advancements in cooling technologies within the high-technology industry, but the rate of adoption for some of these technologies into today's mainstream electronics applications has been relatively slow. The implementation of new cooling technologies is typically limited by cost, conservatism and the ability to stretch an existing solution.

Over the same period, IC and electronic systems have scaled to smaller geometries, resulting in increased power densities. While it is the OEMs that have driven this scaling trend, they have not necessarily been at the forefront of advancements in cooling technology. As a result, already challenging thermal requirements in OEM-based products have become more difficult, creating further thermal challenges that may not be mitigated using historic thermal solutions. This increases the likelihood that new cooling developments come off the "technology shelf" of thermal management providers and become mainstream thermal options. A good example of this would be liquid cooling in some OEMs entertainment PCs. Fundamentally, it also means that continued improvements in cooling technology and their applications within OEM systems require dedicated efforts by companies that specialize in this core competency. The result is thermal interface materials (TIMs) that now require more application-specific, customized thermal results.

How is the industry dealing with the heat removal challenges? There has been a multi-pronged approach to this problem. The more advanced of the cooling technologies include high thermal conductivity and application-specific passive cooling, which encompasses the class of materials known as gap fillers, grease, phase change, insulators and thermally conductive printed circuit boards. Additionally, advanced hardware such as heat pipes and micro-machined heatsinks as well as active cooling agents like thermal modules, microjet, liquid cooling and thermoelectrics round out this group. With the aid of these advanced cooling technologies, a thermal design engineer has a host of tools to draw upon in order to provide the thermal management solution required for system design.

Thermal Interface Materials Provide Advantages

TIMs offer important advantages for companies seeking heating options. TIMs such as gap fillers, thermal greases and thermal conductive insulators enhance the thermal transfer of heat from the electronic component to the active or passive cooling device, which then transfers the heat to the ambient environment. Using such a material will enable OEM designers to increase functional density of their systems, within the constraints of their thermal specification.

A gap filler, for instance, can be used to conduct heat across

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both small and large gaps between heat source and spreader/sink openings. It acts as an interface component for housing a chassis, a large cold plate or shared heatsink. In the past, thermal gap filler solutions were concerned primarily with heat removal, without regard for mechanical or compliancy issues. Today, a gap filler may provide the thermal pathway for a single device or multiple devices, such as discrete passive components on a PC board, where several hundred devices reach a cooling pathway through a single gap filler. In this instance, the gap filler must not only meet the requirements of thermal conductivity, but mechanical compliancy, so that the varying heights of these components as well as their side walls are in complete contact with the gap filler. This requires that the gap fillers be designed to be soft and have high thermal conductivity. This combination of extreme "softness" and high thermal conductivity is relatively new, driven by increased miniaturization. Moreover, these requirements necessitate a strong understanding of materials' behaviors since optimization of one property tends to work against the other.

This class of gap filler also must be able to provide the requisite thermal and mechanical performance at relatively low applied pressures. Increased pressure on the component can cause the solder joint to crack and the PC board to warp. This bifurcation of requirements is a direct result of the increasing application density and miniaturization of electronics components and systems.

Additionally, greases can be designed to be the optimum TIM for MPU applications and have a myriad of uses in telecom, industrial and consumer products when designed with the corresponding performance requirements. Typically, greases are used where individual thermal solutions are developed for a single component, such as a computer's CPU. In the high-performance MPU space, the thermal management limitations for CPU and GPU cooling are of paramount concern in the PC, notebook and server markets. The thermal interface between these devices and the TIM is a bottleneck for the total cooling solution as ICs scale to 45nm. Greases are certainly one potential solution to this problem. The high thermal conductivity, ability to stencil onto a heatsink and low cost make grease an excellent TIM. The paste-like substance provides excellent surface wetting, which replaces the air between the interface's increasing thermal transfer. Therefore, greases are particularly helpful when advancements such as higher thermal conductivity, better surface wetting and thinner bond lines are needed.

Similarly, a phase change material (PCM) is used for more extreme thermal cooling requirements when individual thermal solutions are developed for a single component. PCMs melt at operating temperatures providing low thermal resistance and a thin bond line. The choice to design in a PCM (versus a thermal grease) is highly dependent on the OEM. PCMs tend to be easier to apply and somewhat easier to rework, where as grease tends to provide slightly better thermal performance. Both are good, cost-effective solutions in high-performance applications.

Moreover, applications that require electrical isolation between the component and thermal solution rely on thermally conductive insulators. All of the TIMs provide electrical isolation, but thermally conductive insulators offer guaranteed electrical isolation so that an engineer can insure his designs will function properly. Thermally conductive insulators provide the thermal connection between power devices and a heatsink and are designed to meet the requirements of both cast and extruded heatsinks. Typically, the thermally conductive insulator must be designed to be more rugged than the other interface materials to protect against physical punch through and generally harsher environments than the other TIMs. Typical applications include power transistors and modules in the automotive, telecom, IT (power supply) and industrial markets. Recent advancements in film-based insulators have demonstrated better cut-through performance and increased control of breakdown voltage, in addition to superior thermal performance and cost.

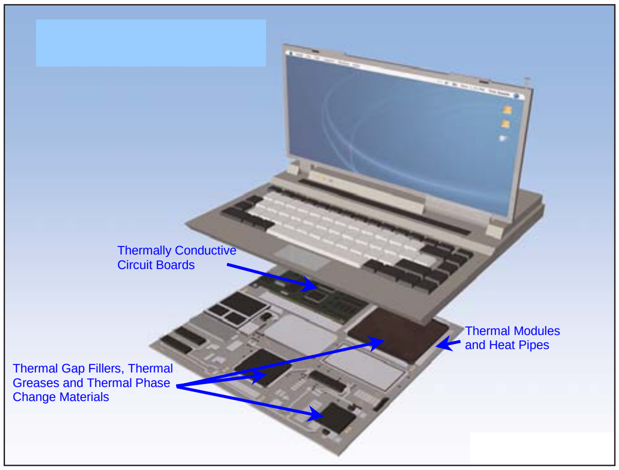

Fig. 1: The above graphic shows typical locations for TIM solutions within a notebook. Not shown are the gap filler battery cooling solutions and charger module insulators and thermal putty solutions.

Gap Filler Applications Offer Alternatives

Figure 1 shows a close-up view of a notebook computer and the locations of many typical TIMs. Inside most real world applications, advanced gap filler applications have evolved to a delicate design balance of multiple "touch points" (cooling more then one component with the sample thermal solution). This blueprint is mainly designed around the die-referenced CPU or GPU. In these designs the vital CPU or GPU is cooled by close tolerance and constant pressure on the mechanical attachment of the thermal solution. The interface material is either a high-performance thermal grease or PCM. The supporting components can be cooled using the same thermal solution, primarily a heatsink fan assembly. In these designs the component used to heatsink the gap is not as closely controlled. There can be a large tolerance between the thermal solution and the component. This is a perfect application for today's gap fillers. The more compliant the material the less the designer needs to worry about improving tolerance to reduce stress on the components. The better the thermal conductivity, the better the thermal transfer, and the cooler the component will run.

Examples of this type of thermal design are included in almost every notebook PC and in advanced graphics cards manufactured today. The thermal solution in notebook PCs cool the CPU and "touch" the chipset and VGA chip. It also cools both primary video and power components. The thermal module touches the notebook chassis, using the chassis to enhance the overall heat dissipation. For all of these applications, "touch point" gap fillers are the best option.

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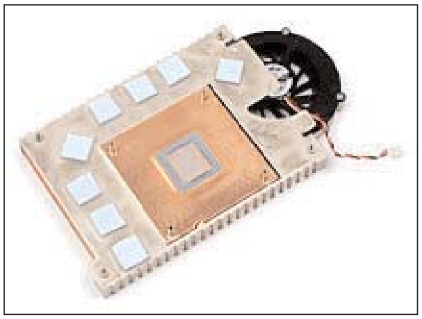
The graphics card cooling solution also is a good thermal design alternative. In this way, the GPU again is cooled by a close tolerance, constant pressure on the mechanical attachment of the thermal solution using either grease or PCM. In the most advanced cards, the video RAM also needs cooling. To cool the memory, the thermal solution is enlarged to cover these components and the heat transferred to the main heatsink/fan assembly occurs via heat pipes. As a result, gap fillers are the appropriate solution to interface the memory of the thermal solution.



Gap fillers also are seeing increased demand across components in large board designs. Network hardware, telecommunication equipment and automated test equipment all rely on gap fillers to help cool the ever increasing number of high-watt density components. These designs can have multiple approaches.

Weighing All the Factors

As the trend toward shrinking electronics at both the chip and board levels continues, companies should weigh all heat removal challenges involved, including cost, quality and technological requirements, before deciding on a route to pursue. In the near term, a persistent drive toward reducing the cost of TIMs, such as gap fillers, grease, PCMs, insulators and thermally conductive printed circuit boards, or other advanced cooling solutions will continue. These advanced cooling options provide a thermal design architect with a variety of tools to customize the right thermal management solution needed for their particular design. Therefore, the thermal solution must meet the requisite OEM cost target.

As the density of components increase-particularly in regard to mechanical considerations-a rise in the need for thicker gap fillers is likely to occur to allow mechanical damping between and within a component along with thermal syncing among housings and components. In these cases, electronics makers need to weigh mechanical and thermal properties, while insuring best cost per unit of performance.

Furthermore, the drive toward miniaturization naturally results in increased PC board hybridization, which in turn increases the need for thermally conductive PC boards. The components on these boards will, in many instances, interface with a TIM, so it is critical that the thermal requirements of the design be understood early in the design cycle to insure that cost and performance targets are met.

Once a suitable tailor-made solution is in place, companies have to be vigilant about the quality and thermal reliability of their systems that affect their end product. Engineers are spinning out new designs every six months that in many instances need new, different or better technological solutions than the previous generations provided. At that rate of change, it would be easy not to maintain the level of quality that customers continually demand. The only solution is to change at the same rate or faster than customers.

Strengthening the customer relationship and understanding what their needs are three to five years out also allows time to develop a scalable and economically viable range of technical solutions that meet set quality and performance requirements. Serving the global customer on a local basis also gives the supplier a vital bird's eye view of the situation. It's an important issue from a customer's perspective.

Today, the increasing complexities of thermal requirements are driving application-specific TIM requirements along with the adoption of more advanced cooling solutions. Customized thermal properties are on the rise as circumstances shift, and device manufacturers must choose the right path for the success of their products and customers.

Laird Technologies is a producer of electromagnetic interference [EMI] shielding materials, thermal interface products and wireless antennas solutions for the telecommunications, datacommunications, computer, general electronics, network equipment, aerospace, defense, automotive and medical equipment industries. For more information please visit www.lairdtech.com.

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