Thermal Management Help Hardworking Chips

Elevated temperatures being the enemy of component reliability, thermal management demands careful attention to ensure the end product will achieve the required design lifetime. Effective thermal management begins at the semiconductor level, with careful component selection, focused on efficiency to minimize power dissipation, and judicious use of power-down modes. Hardworking components can be expected to require a heatsink. **Mark Patrick, Technical Marketing Manager EMEA, Mouser Electronics, UK**

Today's electronics designers face unrelenting pressure to increase system power density, or to add new and more impressive functionality within smaller product dimensions. Either way the result is that components may be working harder, or crammed within a smaller space, or both — placing upward pressure on operating temperatures (Figure 1).

Design for thermal management

Design for thermal management can, and should, begin at an early of the project. It is possible to minimize thermal challenges later by selecting components carefully at the beginning: in power applications this could include choosing the latest and most efficient MOSFETs or IGBTs. More generally, system-level power management, taking advantage of chip idle modes and opportunities to power-down unused components or subsystems minimizes the quantity of heat that must be dealt with through dedicated thermal management.

Ultimately, high-power or high-performance systems typically require heat to be removed from hardworking Silicon junctions into the ambient atmosphere using a mechanism such as a heat spreader, cold plate, or one or more heatsinks. Moreover, the full extent of any thermal-management challenges may not be known until later in the project, as the design becomes finalized. At some point, inevitably, engineers will find themselves needing to design-in a heatsink and optimize its performance to get the maximum heat out in relation to its size and cost.

Removing the heat

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To ensure the heatsink is as effective as possible, it is first important to minimize the thermal impedance at the join between heatsink and package surface so that heat can transfer efficiently out of the package into the heatsink. The second important consideration is to maximize the heatsink surface area in relation to its volume for optimum dissipation, working within PCB-area and assembly-height restrictions.

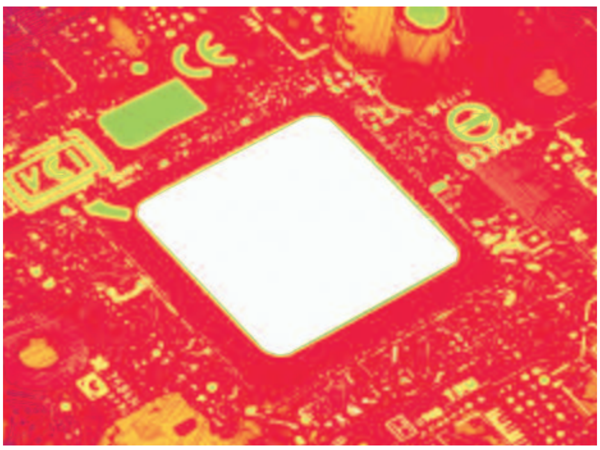


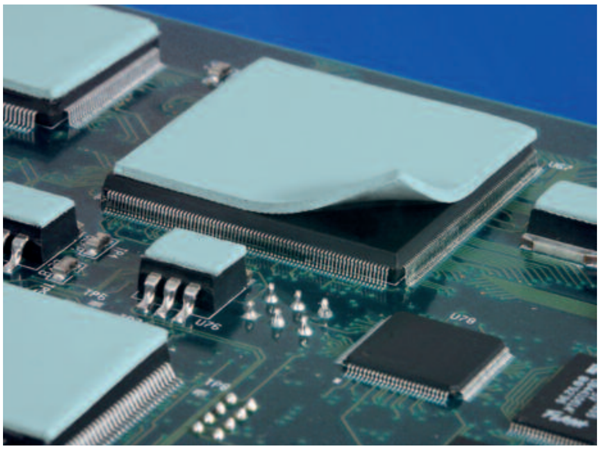
Figure 1: Today's electronics face upward pressure on operating temperatures

Optimizing thermal interfaces

Where the heatsink is attached to the component, surface roughness and non-planarity displayed by both parts unavoidably trap pockets of air that prevent efficient transfer of heat into the heatsink. A thermal interface material (TIM) is applied at the join to eliminate the air. The TIM must have good flow and wetting characteristics to counter the effects of the surface roughness. To correct for non-planarity, the TIM must conform to both surfaces with low external stress to avoid placing excessive pressure on the component.

A wide variety of TIM types and formulas is available, including thermal greases, phase-change materials, liquid dispensed cure-in-place fillers, thermal adhesives, films, laminates, and pads. These present designers with many options to satisfy not only the thermal-performance requirements but also compatibility with automated assembly processes, physical performance such as response to long-term thermal cycling, and special requirements of the application – such as silicone-free materials that are often required to prevent fogging of optical products or automotive lighting. Other factors to consider are electrical isolation, tear resistance, and whether the chosen material is capable of being re-used or replaced/re-applied if the assembly is subjected to rework in the factory or repair in the field.

Among the variety of TIM types available, thermal gap-filler pads are a convenient solution that can be supplied as bulk sheets or in custom sizes to fit specific component packages. Pads can be placed by hand or using an automated mounter, and so can be integrated with inline surface-mount assembly if required. Inherent natural tack on one or both sides of the pad



LEFT Figure 2: **Gap Pad from Bergquist helps to significantly improve thermal performance**

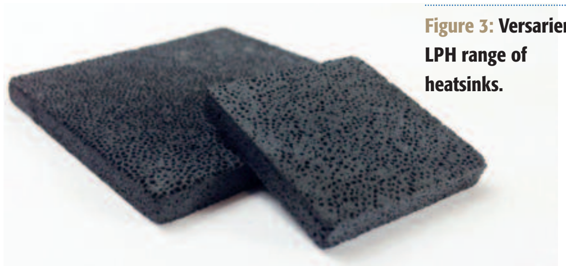


Figure 3: **Versarien's LPH range of heatsinks.**

enables placement without requiring an adhesive, which not only simplifies manufacturing but also saves a potentially thermally-impeding extra layer.

A wide range of formulas is available, offering numerous combinations of thermal conductivity, softness, wetting characteristics, and cost. Among them, Gap Pad® 5000S35 is a recent addition to Bergquist's S-class (Soft) highly conformable materials. Gap Pad® 5000S35 has the highest thermal conductivity within the S-class, at 5.0 W/m.K, with a low modulus of 121 kPa to minimize the stress placed on components when compressed as the heatsink is clipped or bolted in place.

For even more stress-conscious applications, Bergquist also has HC (High-Compliance) and ULM (Ultra-Low Modulus) Gap Pad families with thermal conductivity up to 5.0 W/m.K and 3.5 W/m.K respectively. There are also Value Performance as well as Extended Performance (VO, VO Soft, or VO Ultra-Soft) Gap Pad families, offering a broad spectrum of cost, conductivity, and conformability options.

On the other hand, specialty Gap Pad families give designers extra options including silicone-free (SF) product lines with thermal conductivity up to 3.0 W/m.K. While the S-class range have extremely low extraction values compared to other silicone-based materials, Gap Pad 1000SF, 2000SF, 2202SF, and 3004SF provide the ultimate protection for silicone-sensitive applications.

The thermal properties of gap fillers can also be combined with suppression of electromagnetic interference (EMI) to provide a convenient two-in-one solution; electrical noise issues being another commonly encountered source of last-minute headaches for product developers. Gap Pad EMI 1.0, also produced by Bergquist, is electrically isolating, absorbs interference such as cavity resonances and crosstalk at frequencies of 1GHz and higher, and is at the same time highly conformable with low hardness, good wetting properties, and thermal conductivity of 1.0 W/m.K.

Designing with heatsinks

As far as the heatsink is concerned, a huge variety of sizes and shapes are available off the shelf from manufacturers such as Aavid, Cincon, Wakefield Vette and others. Manufacturers' standard product ranges typically include models that are designed specifically to fit common semiconductor packages, such as LGA, QFN, or BGA packages, popular power outlines including D2PAK or TO-220, or standard power modules such as quarter- or half-brick. Choices also include heatsinks optimized for standard System On Module (SOM) sizes such as SOM-4461, or designed for fitment to IGBT modules of various sizes.

The thermal resistance, quoted on the datasheet in K/W, helps designers calculate the operating junction temperature of the chip, assuming the power dissipated and the ambient temperature are known, and the thermal resistances of the package and TIM are also taken into account. If the calculation indicates the junction temperature will be above the desired target to ensure the required reliability, a heatsink with lower thermal resistance may be needed.

Alternatively, forced air cooling using a fan may be applied to increase thermal performance. Although improvements to fan materials and construction, and new electronic drivers, have extended the typical lifetime of cooling fans, they still have appreciably shorter lifetime than the silicon-based components they are cooling. There are other drawbacks, too, such as increased bill of materials and engineering costs, and the fact that sealing the enclosure is not possible. If a filter is provided, to prevent the fan drawing dust into the equipment, this must be regularly cleaned to maintain cooling effectiveness. Hence, if possible, passive cooling without a fan is usually preferred.

The typical approach to reduce the IC's junction temperature without resorting to a fan is to specify a larger heatsink. This, too, may be undesirable, or even unworkable if the space inside the enclosure is not accommodating. A custom heatsink may be designed to provide a larger cooling-surface area within the prevailing space constraints, but can be an expensive solution that may delay the project.

Advanced heatsink Materials

There is an alternative: an innovative new copper-based foam material, VersarienCu™, created using a process developed at the University of Liverpool. Its structure, featuring fine, open, interconnected pores, is highly suited to thermal transfer applications. Heatsinks made from VersarienCu outperform comparably-sized heatsinks by up to 6 K/W. Versarien Technologies heatsinks are also coated with a thin, hard layer of high-temperature copper oxide, which increases emissivity thereby increasing the heatsink's radiant properties.

The large surface area of the interconnected pores, combined with the high thermal conductivity of copper, gives designers freedom to specify a smaller or lower-profile heatsink, or to gain the advantage of improved thermal performance in the same physical envelope.

There are 10 standard products in the current Versarien LPH range of low-profile heatsinks, covering sizes from 10 mm x 10 mm x 2 mm up to 40 mm x 40 mm x 5 mm. The largest size has a thermal resistance of 17.4 K/W at an applied load of 5 W.

Conclusion

Effective thermal management begins at the Silicon level, with careful component selection, focused on efficiency to minimize power dissipation, and judicious use of power-down modes. Hardworking components can be expected to require a heatsink, and a wide variety of thermal interface materials and off-the-shelf metal heatsinks are available to help extract heat as effectively as possible. Designers targeting an extremely small outline or low profile, or facing difficult thermal problems late in the project, can now turn to new and advanced VersarienCu heatsinks to overcome their challenges.