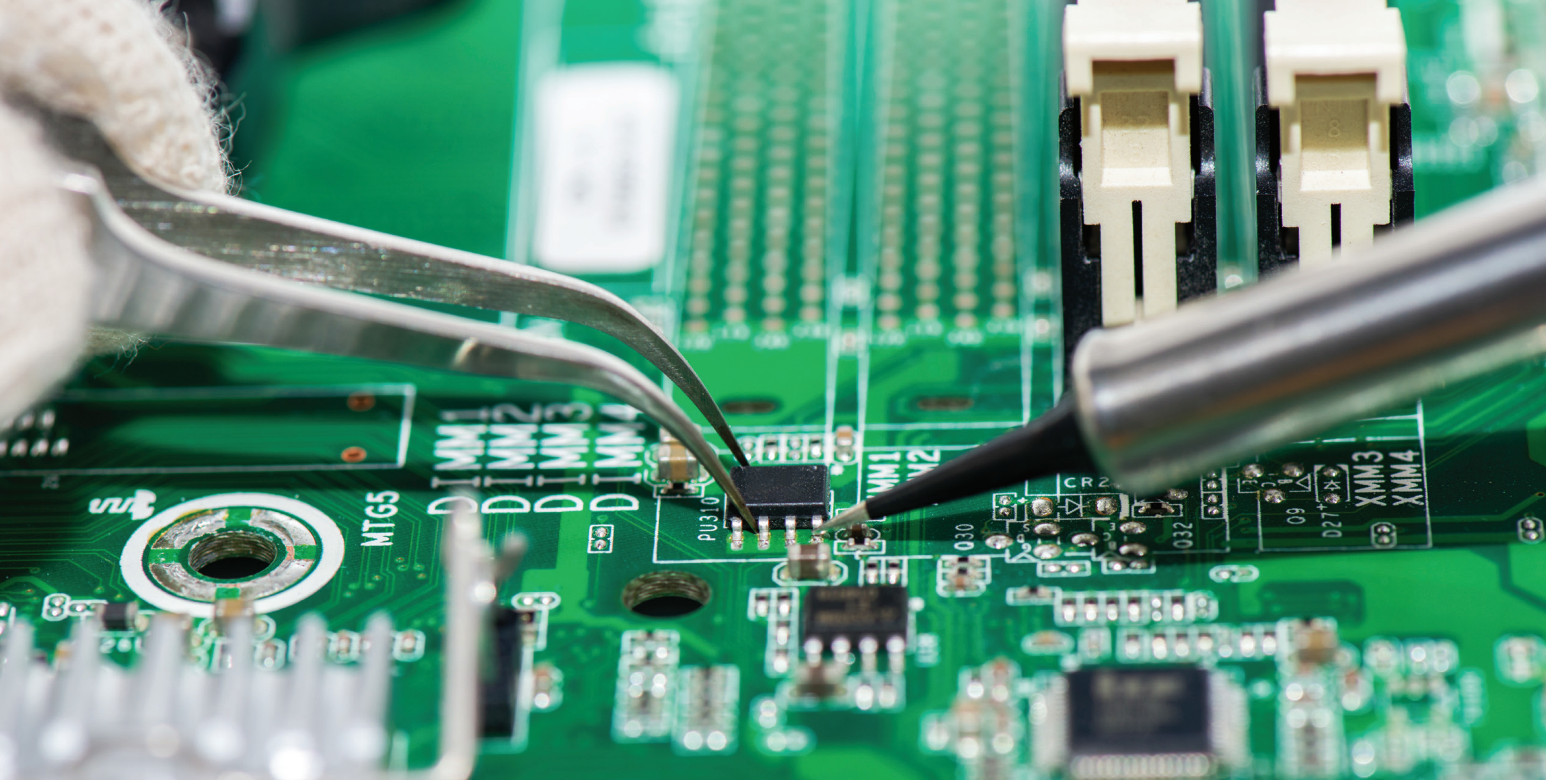

DIGITAL INDUSTRIES SOFTWARE

Heatsinks here, there, everywhere!

Why not just shove a heatsink on top of every heat-generating component?

Executive summary

Heatsinks are often perceived to be the magic answer to all electronics cooling challenges. A heatsink makes heat spread out, so that it passes to the air over a much larger surface area than it would otherwise. Air then carries the heat away, cooling the electronics that generated it. So, why not place a heatsink on top of any thermally critical component?

Simulation can illustrate the answer. With a 3D thermal simulation and analysis tool, such as Simcenter Flotherm, product designers can model a product, or part of a product, and then observe a wealth of information about the air and heat flow within and around it. Simulation aids informed decisions about how to use heatsinks and where to put them.

We set up an experiment to answer this question

We staged two different types of surface mount packages on a PCB, with and without a heatsink, and observed the results (figure 1).

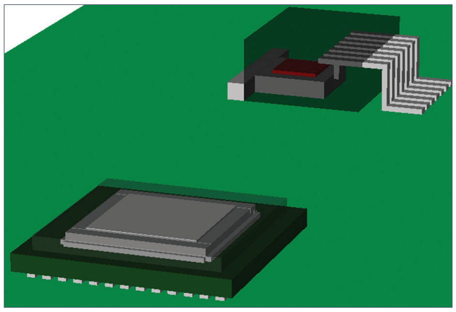

Figure 1. Simcenter Flotherm model of a BGA and a TO263 package with encapsulate.

The package in the foreground is a flip chip, ceramic ball grid array (BGA), commonly used for microprocessors. A piece of metal over the die helps to spread and induce the heat to the top of the package. The package in the background is a seven-lead TO263 – a much simpler package design commonly used for discrete power devices. In our models shown here, the encapsulate is made a little transparent so we could see the inside.

In Simcenter Flotherm™ software, we placed these two devices on a 2S2P high-k–type test board and put into an air stream at 35 degrees Celsius, moving at three meters per second (approximately 600 lfm). Their junction temperatures, that is, the temperature at the heat source, were noted in the silicon die itself. A standard, aluminum, extrudedplate, fin heatsink was then placed on the top of each package, and the junction temperatures were noted again (figure 2).

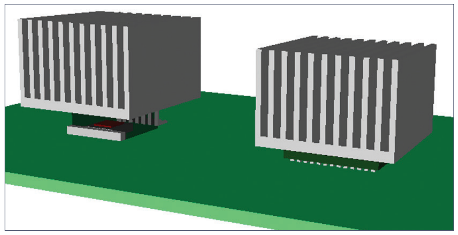

Figure 2. Devices on a circuit board with proposed heatsinks.

Best practice is to look at the ratio of temperature rise above ambient when comparing and contrasting the thermal performance of two or more electronic products or configurations. The junction temperature rise above ambient when a heatsink was used on the BGA package was 27 percent of the value without one, a massive drop. For the TO package it dropped to 81 percent of the temperature rise without a heatsink (figure 3).

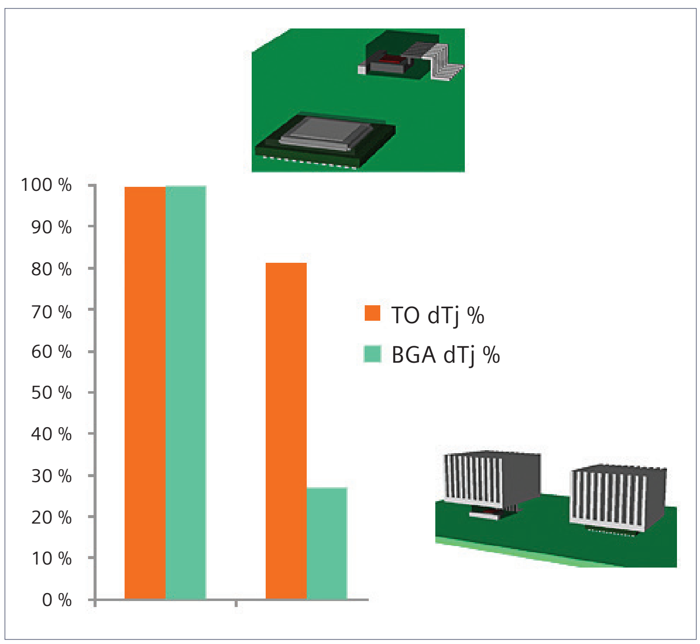

Figure 3. Ratio of temperature rise with and without heatsinks.

The temperature of the TO package dropped much more than was expected. Internal package construction drives both the type of heatsink chosen and its location on the package. Suffice to say, not all package styles are equal. For heatsinks to work effectively, they have to be placed where there is heat to sink (or area to extend). Additionally, an understanding of the air-flow behavior around the package can explain this unexpected thermal performance.

Understanding underlying thermal behavior – Heat flow budgets

We observed the heat flow within each package before a heatsink was deployed to understand why there was such a difference. The black, heat-flux vectors in figure 4 show how the heat left its source on the active layer of the die and spread out through the package. Low heat-flux vectors were clipped out to clarify the image.

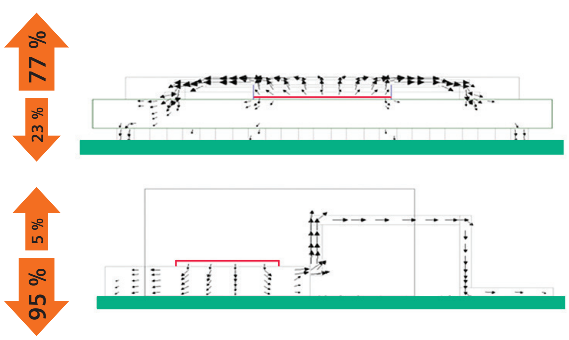

Figure 4. Heat-flow pattern for the BGA (top) and TO (bottom) devices without a heatsink.

Thermal design engineers often characterize heat flow for heat-flow budgets, which is a description of the dominant heat-flow paths, that is, the percentage of the total heat that flows to each area. Sometimes such budgeting is used to summarize the proportion of heat that passes through a surface by convection, conduction, and radiation.

For the BGA without a heatsink, 77 percent of the heat flowed directly up through the die and passed near the top surface of the package. This was caused by the metal spreader and slug placed on the top of the package. For the TO package, 95 percent of the heat preferred to pass directly to the PCB, as was intended in the design.

So, what happens to the budget if we place a metal heatsink on top of both packages (figure 5)?

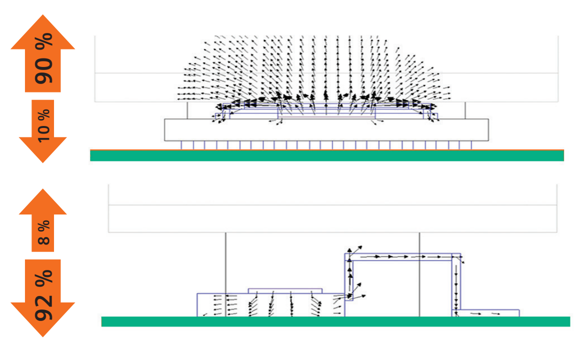

Figure 5. Heat-flow pattern with heatsink for the BGA (top) and TO (bottom) devices.

For the BGA, the 77 percent of the heat that was going up before the heatsink was placed on top has now been upped to 90 percent. The heatsink provided a welcome helping hand to the metal spreader and slug, which were already inducing heat to the top of the package. The result was a substantial reduction in junction temperature rise. The more readily the heat could leave, the lower the temperature rise.

The TO package only had a three percent shift in the budget. Why the 19 percent reduction in junction temperature rise? The answer to that lies not in the conductive effects of the heatsink, but in the effect the heatsink has on the airflow.

The heatsink funnels more air over the surface of the PCB around the component. This can be seen in the above plot of air speed (figure 6), just above the board surface, comparing moving air (greater than one m/s) with and without heatsinks. This increased air speed, washing over the board surface, more effectively removing the heat that had already passed down through the TO package and spread into the board, thus resulting in the 19 percent decrease in temperature rise above ambient. No coupling occurred in this example between pressure loss, flow rate, and thermal performance, which is what we would find in reality.

With the help of Simcenter Flotherm, we can make more informed decisions about whether to add a heatsink to an electronic package. For the BGA, the heatsink provided a substantial increase to the cooling ability of the package. The BGA package is designed to induce heat to the top of its construction. When we placed a heatsink on top of a BGA, it absorbed and dissipated a majority of the heat produced. However, the TO package directs heat down and into the circuit board, so a heatsink placed on top of the TO package did not appreciably change the dissipation. In this case, a heatsink might not be a cost-effective option for cooling the TO package. So no, a heatsink everywhere is not the magic answer for electronics cooling.

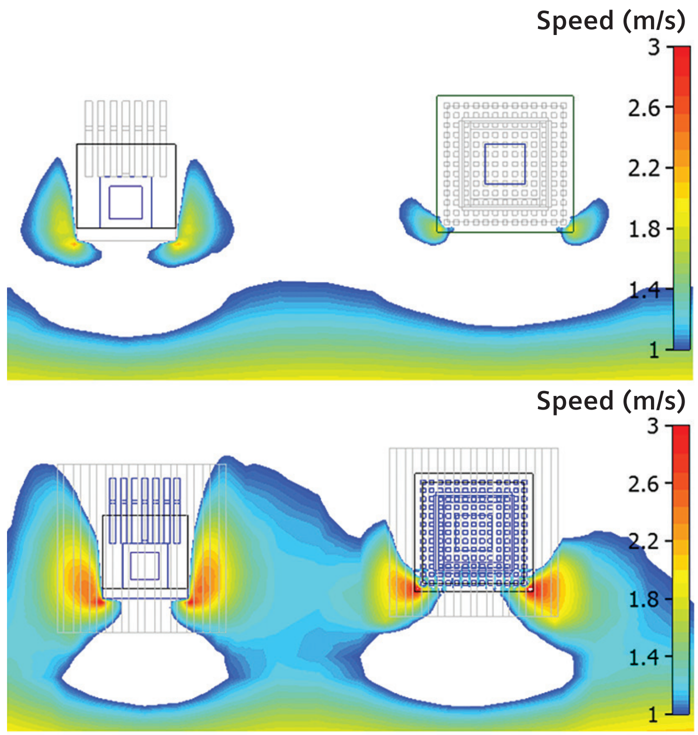

Figure 6. A fixed-flow environment with limited allowance of bypass.

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