FINDING THERMAL BOTTLENECKS AND SHORTCUTS IN ELECTRONIC DESIGNS

Mentor Graphics FloTHERM is the leading CFD thermal analysis solution in the electronics vertical market. Innovative additions to the post-processing tools in FloTHERM 9 open up a new realm in thermal analysis, enabling designers to understand ***why*** a design is running too hot. Two newly-developed quantitative measures and displays help FloTHERM 9 users visualize critical—and formerly invisible—thermal characteristics in their designs:

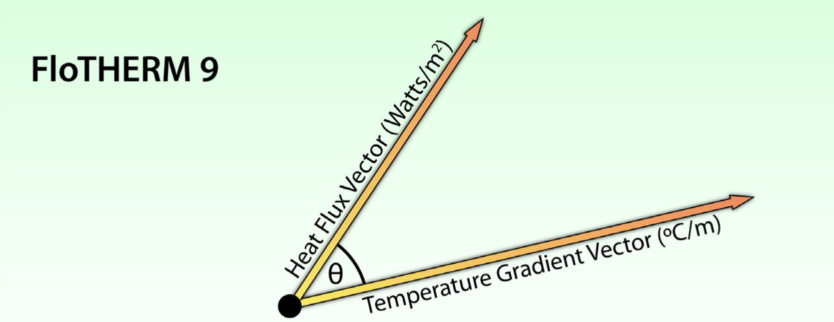
- The **Bottleneck (Bn) number** identifies flow paths that carry high heat but at the same time, resist the flow of that heat.
- The **Shortcut (Sc) number** reveals opportunities for alternate and more efficient heat flow paths; in other words, shortcuts toward cooler areas.

Ultimately the Bn and Sc values add to the designer's understanding of the ease with which heat leaves a system, and then help him or her reconfigure heat flux distribution to improve performance. Until now there has been no way to identify such thermal bottlenecks and shortcut opportunities within a design. A redesign informed by the Bn and Sc data can do more than just recognize bottlenecks; it can also bypass them.

INTERPRETING THE MATH

The measure of heat flow through a particular cross-sectional area is known as heat flux. The presence of a heat flux vector will always be accompanied by a temperature gradient vector. These two terms are the stock in trade of CFD thermal analysis tools such as FloTHERM. The interaction of the two is essentially an index of thermal resistance. At a given heat flux value, the greater the temperature gradient, the larger will be the thermal resistance. Again, the two vector values are inherent in FloTHERM analysis and are the underlying data that support conventional heat distribution displays.

In Figure 1 the length of the heat flux vector arrow expresses the Heat Flux Magnitude and similarly, the length of the temperature gradient vector arrow defines the Temperature Gradient Magnitude. Here the two vectors are widely misaligned for the purpose of illustration.



Bottleneck Number (Bn):
Heat Flux Magnitude **x** Temperature Gradient Magnitude **x** |Cos (θ)|

Shortcut Number (Sc):
Heat Flux Magnitude **x** Temperature Gradient Magnitude **x** |Sin (θ)|

Figure 1: Calculating Bn and Sc numbers from temperature data. For both entities the product is normalized such the maximum value is 1.0.

The Bottleneck number is the ***dot*** product of the two vector quantities. As shown in Figure 1, at each point in space where a heat flux vector and temperature gradient vector both exist, the Bn scalar at that point can be calculated. If the two vectors are perfectly aligned (very improbable in the real world), then Cos (θ) =1 and the Bn number is purely the product of the vector magnitudes. The metric system units for both the Bn number and the Sc number are WdegC/m^3.

High Bn values indicate large heat flows attempting to pass through large thermal resistances. These are the true thermal "bottlenecks" in the definitive sense of the word, and they are accompanied by a larger temperature gradient.

The Shortcut number's scalar value at any point is calculated as the ***cross*** product of the heat flux and temperature gradient vector magnitudes. Large Sc numbers reveal areas in which heat is not moving directly toward a significantly cooler region. These areas are candidates for a new heat transfer path.

REAL-WORLD RESULTS

Figure 2 illustrates the Sc concept. In a temperature distribution view of this circuit board, the BGA device's hot areas would be highlighted with a "hot" color, usually orange or red. But Figure 2 is not a heat distribution view. Instead, it displays Sc values, and now the red region symbolizes not temperature but an area that will benefit most from a better heat transfer path. Here the Sc plot indicates a relatively efficient ***convective*** heat transfer locally, which offers an opportunity to reduce the temperature increase by adding a ***conductive*** path—a common finned heat sink.

In this design project, a Bn analysis pinpointed a problem area, and the Sc analysis has highlighted a solution. The result is a substantial decrease in the junction temperatures (T_j) within the BGA.

In another recent project, a similar component mounted within an enclosure saw a 74% reduction in T_j after a heat transfer solution suggested by the initial Sc analysis was installed, and a further 58% reduction after installing a more integrated heat path guided by a second Sc analysis.

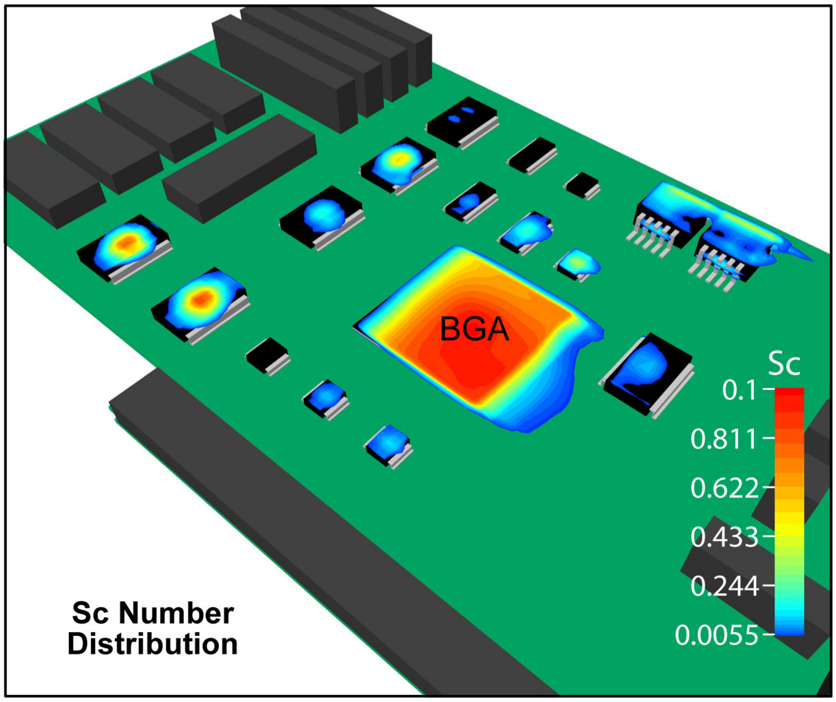


Figure 2: Sc number distribution (not temperature) on a circuit board. The red areas reveal the best opportunities for heat path improvements.

Thermal simulation is now a routine part of the electronic design process, as engineers deal with increasing layout and power density in products of all kinds. FloTHERM 9 can easily detect thermal bottlenecks and shortcuts, offering a priceless advantage for today's time- and budget-constrained design projects.

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