Avoiding meltdown

Thermal-simulation software can help keep hot mobile devices running cool.

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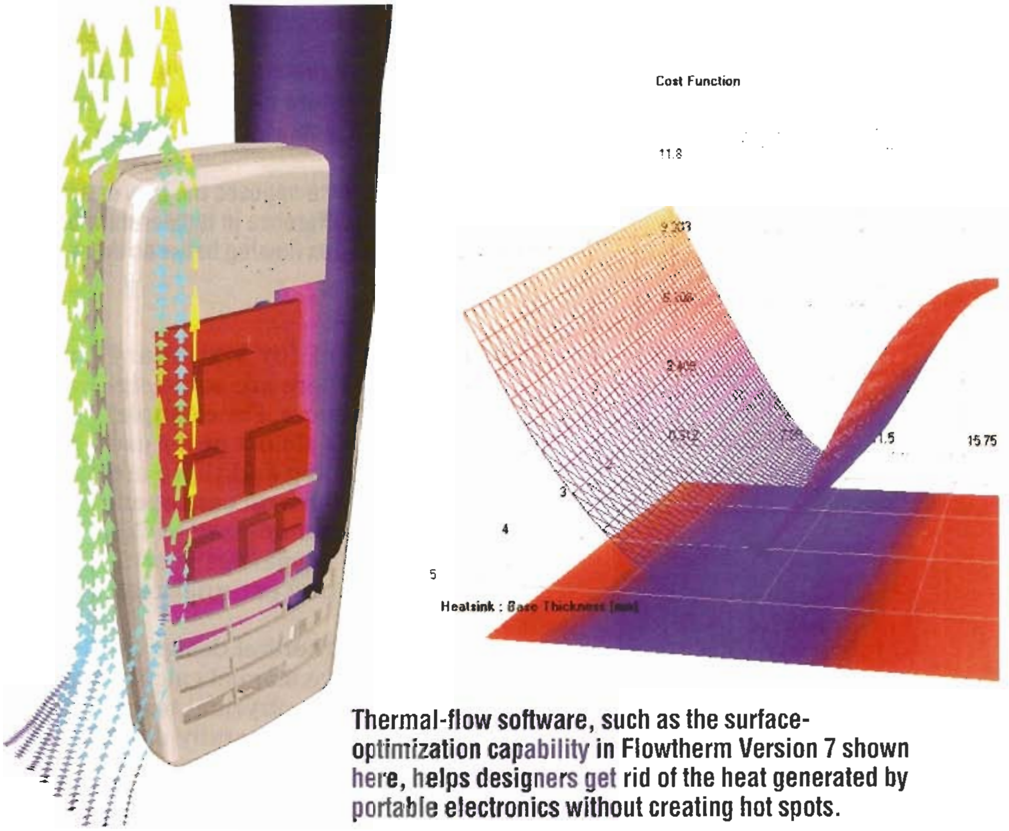


Thermal-flow software, such as the surface-optimization capability in Flowtherm Version 7 shown here, helps designers get rid of the heat generated by portable electronics without creating hot spots.

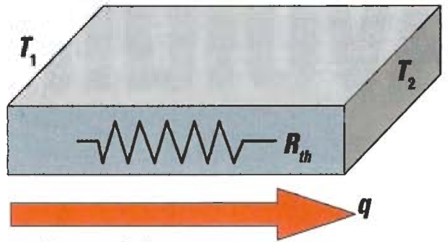
It's no secret that the mobile-device market is the primary driver of innovation within the electronics industry. But the small size of modern mobile devices also creates thermal-management challenges. Cramped corners in mobile devices reduce internal airflow and lower the maximum allowed external temperature.

Thermal simulation helps identify and resolve cooling problems in leading-edge mobile designs. For example, some of the latest mobile phones feature a 3.2-megapixel camera, video recording and playback, a digital music player, and a full Web browser. Each function generates heat. At the same time, the physical size of the phone is rapidly shrinking, limiting airflow and reducing the surface area available for cooling the device.

In addition, engineers may have a tough time measuring how well their designs dissipate heat. Thermocouples can act as heat sinks on miniaturized packages, so recorded temperatures may be inaccurate. Thus, thermal simulation may give more accurate temperature readings than what's possible with simple thermal probes.

Thermal simulation of mobile devices follows the same general ap-

Calculating thermal resistance



$$R_{th} = \frac{\Delta T}{q}$$

where:

R_{th} = thermal resistance between two points
ΔT = temperature difference between the points ($T_1 - T_2$)
q = heat flux flowing between the points

Thermal resistance opposes the flow of heat through a body. It's calculated by measuring the difference in temperature between two points divided by the amount of heat flux flowing between them.

proach as that for stationary devices, but there are some significant differences. For example, mobile devices almost never use forced-air cooling and there are usually strict limits on case openings. Accurate modeling of the case material properties is critical for predicting external case temperatures.

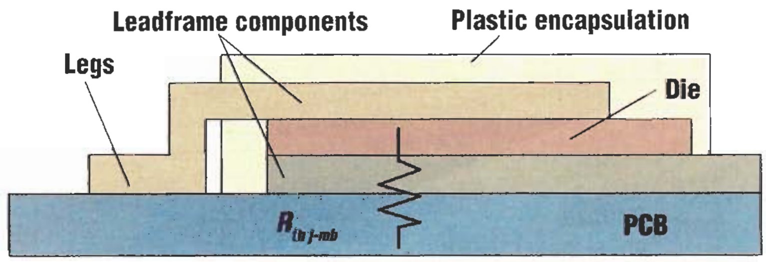
Traditional thermal design involved extensive manual calculations verified by physical tests. The calculations generally used the thermal resistances found on device data sheets. Thermal resistance resembles electrical resistance, except it opposes heat flow rather than electricity. The value quantifies the flow of heat energy along predefined paths by calculating the change in temperature between two points divided by the rate of heat flow.

Test methods used to determine thermal resistance are listed in Jedec specifications JESD51-1 through JESD51-10. The thermal-resistance values generated under these highly specific test conditions are unlikely to match those in real applications. Obviously, this raises questions about their accuracy. In particular, the method of measuring the thermal resistance from the junction to motherboard, $R_{th\ j\text{-}mb}$, makes no allowances for PCB sizes, shapes, or compositions differing from those defined in the test spec. It also does not account for the effects of other nearby heat sources and the influence of the enclosure. Further, the concept of $R_{th\ j\text{-}mb}$ is limited because it only considers one component within a larger, more complex network of thermal resistances.

Thermal-simulation software already helps analyze complex thermal scenarios in stationary electronics that involve coupled heat transfer by conduction, convection, and radiation. These same methods apply to mobile devices as long as engineers consider several subtle but still significant differences.

As for any engineering analysis, the first step in a simulation is to collect all information relevant to the simulated device. For a typical mobile device, this includes the specs of all components on the PCB including their power dissipation, the construction and orientation of the PCB, the size, shape, and composition of the

The derivation of $R_{th\ j\text{-}mb}$



A single, simple conduction path from device junction to package mounting base.

The test methods used to determine thermal resistance are specified by Jedec specifications JESD51-1 through JESD51-10. However, Jedec methods do not account for different PCBs differing in size, shape, or composition from those specified in the standard. Likewise, the use of $R_{th\ j\text{-}mb}$ is limited as it is only one specification in a much larger, more complex network of heat sources and thermal resistances.

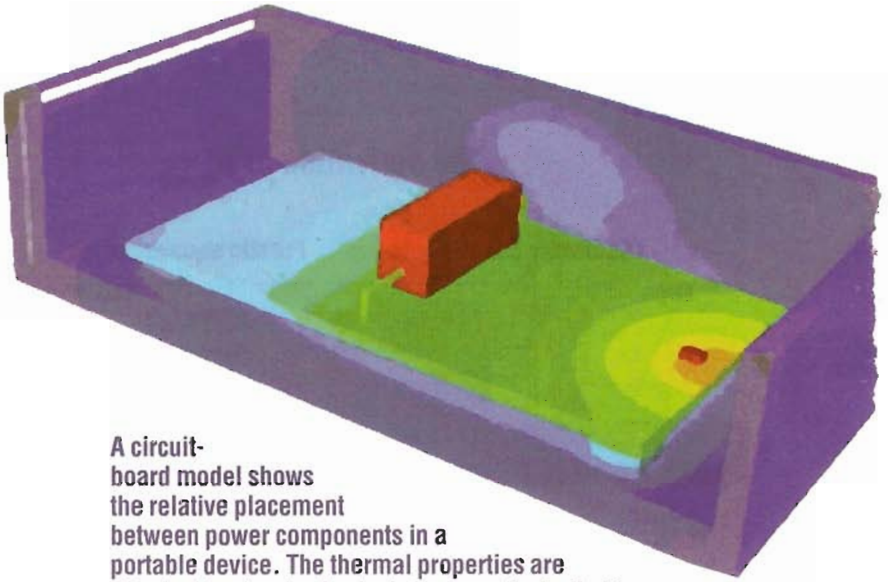
enclosure, the anticipated ambient conditions, and any other relevant physical attributes. Engineers model the component geometry using a variety of primitive shapes or cuboids with relevant physical properties attached to each shape. Properties such as material composition, surface properties, thermal qualities, and radiation attributes, attach easily to the cuboids.

Enclosure construction and material details are important for analyzing thermal performance. Fortunately, the software libraries for thermal-simulation software include properties of many common and exotic materials.

It can be time consuming to accurately simulate components with intricate geometry, such as semiconductors and heat sinks. So many component vendors have developed behavioral models that predict the temperature of the package at such critical points as the junction, case, and board to help save time. The models drop into a full thermal design simulation with all parameters already programmed.

For example, SmartParts3D is a free Web database that holds certified analysis models and data-sheet information for a wide range of semiconductors, printed-circuit boards, power supplies, heat sinks, enclosures, capacitors, grilles, and many other components. Design engineers can download the information from many different vendors, search and compare parts in the library by attribute and performance qualities, and drop different parts into a model to compare thermal performance.

Semiconductors that handle a lot of power impact simulation results the most. A typical example is the N or P-channel MOSFETs used to switch power rails in many mobile devices. The MOSFETs work



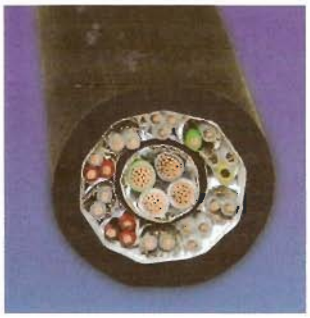
A circuit-board model shows the relative placement between power components in a portable device. The thermal properties are attached to simple physical shapes called cuboids. Thermal-simulation software depicts the thermal gradients developed by all heat sources based upon expected power output levels. The error between the predicted and actual temperature rise was less than 2%.

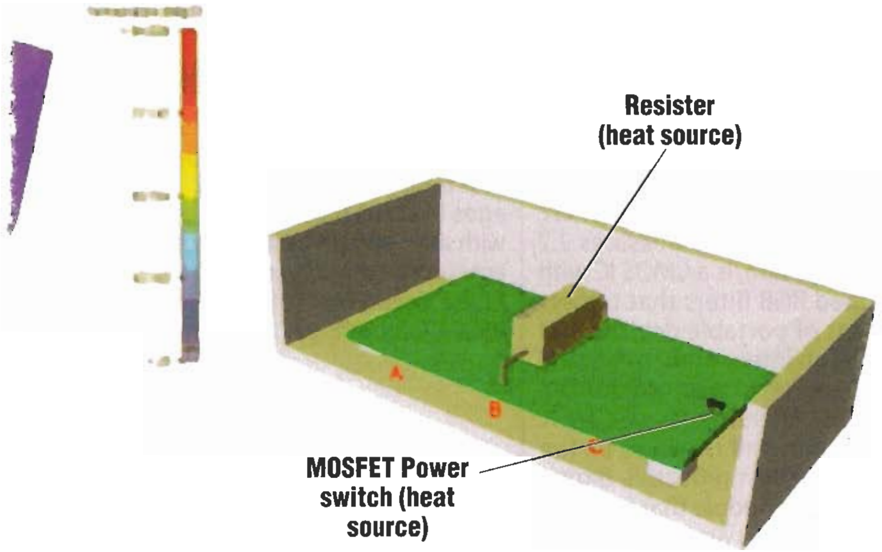
in an environment where relatively few cooling options are available. An example is the NXP PMN23UN that provides an on-resistance of 28 mΩ in a TSOP6 package of 9.3 mm^2. The device finds use in such applications as load switches or driver FETs for dc/dc converters. Just a 42% jump in load current more than doubles the power dissipation within the device.

An example shows how thermal simulation typically proceeds. Consider a charge controller for a mobile phone. A simulation with Flotherm software from **Flomerics Corp.** takes into account other sources of heat in the device. The Flomerics software possesses many prebuilt models that cut the time needed to set up the thermal simulation.

A prototype was built with steady-state MOSFET power dissipations of 0.5, 0.75, and 1 W. Designers measured the corresponding MOSFET-junction temperature rise for each of the three power dissipations using the body-diode thermometry method described in Jedec specification JESD51-1. Then they added a second heat source in the form of a resistor dissipating 1 W. Three simulations took place with the resistor in three different positions while the MOSFET power dissipation stayed constant at 0.75 W. The resulting simulation was able to predict the rise in junction temperature with an error ranging from 1.1 to 1.9%.

Though the TSOP6 package worked acceptably, clearly its temperature rise would become an issue as power dissipations rose. Future needs appear to dictate a radically different package type. The proportion of footprint area occupied by leads becomes more significant as packages shrink. In that regard, the nanoPAK package was developed to reclaim board space by eliminating leads while enhancing thermal performance. The new package contacts the PCB through a copper pad rather than the relatively thin rails used





Thermal simulation model

in the TSOP6. A thermal simulation predicted the performance of nanoPAK packages before any engineers invested time or money on prototypes. The simulation predicted that nanoPAK packages would perform substantially better thermally than TSOP6 packages. Physical testing results demonstrated that $R_{th\ j\text{-}mb}$ values for the nanoPAK package were about half the level of the TSOP6.

Always keep in mind that thermal simulation has limitations. The simulation results are only as good as the data used to create them. It may be tough to get the properties for less common materials. When thermal data is not available, engineers may be forced to make educated guesses based on the properties of other similar materials. Finally, when comparing simulations to empirical data, consider the potential for error in physical measurements as well as in the simulation. For example, both thermocouples and thermal-imaging cameras have inherent potential inaccuracies that may contribute to variances between measured and simulated temperatures.

Even with these limitations, there are advantages to simulating the thermal design of mobile devices. Designers can quickly evaluate concept designs and correct thermal problems long before the prototype phase. Many companies that perform thermal simulation regularly at the concept design phase discover it is almost never necessary to build additional prototypes to solve thermal problems. Thermal-simulation software also provides much more information than physical testing. Detailed 3D graphical information on pressures, temperatures, and airflows help engineers quickly optimize their design. **MD**

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