

Predicting Circuit Board Hot Spots with Electro-thermal Cosimulation

Multiphysics analysis with Slwave and ANSYS Icepak accurately determines thermal distribution on complex PCBs.

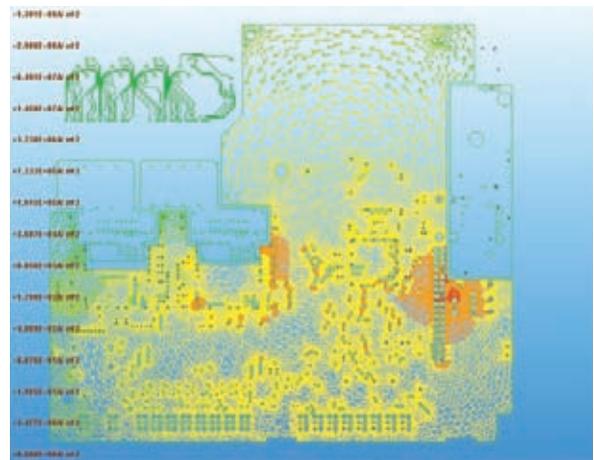
By Aaron Edwards, Technical Account Manager, and Kamal Karimanal, Lead Technical Services Engineer, ANSYS, Inc.

Excessive heat is the enemy of electronic parts, especially integrated circuits (ICs) in densely packed, power-hungry electronic devices. Increased levels of electrical current requirements in these applications must be considered in the printed circuit board (PCB) design to combat the generation of joule heat.

Energy efficiency can be optimized by minimizing current density levels, even at the expense of slightly higher resistance paths. However, a generally energy-efficient circuit can run the risk of overheating at spots due to spikes in current flow rates at local bottlenecks in the circuitry. While such bottlenecks can be identified through board-level current flow simulations, thermal analysis is needed to ensure that heat dissipation is sufficient and that the temperature rise due to current spikes is below recommended levels.

Current flow and thermal analysis simulations previously were performed separately, but now they can be combined in a multiphysics-based board-level electro-thermal cosimulation provided by a link between the Slwave electromagnetic field solver and the ANSYS Icepak thermal analysis solver for electronics packages. In this way, these two solvers work together as next-generation tools that enable engineers to accurately predict heat distribution and temperature in complex circuit boards.

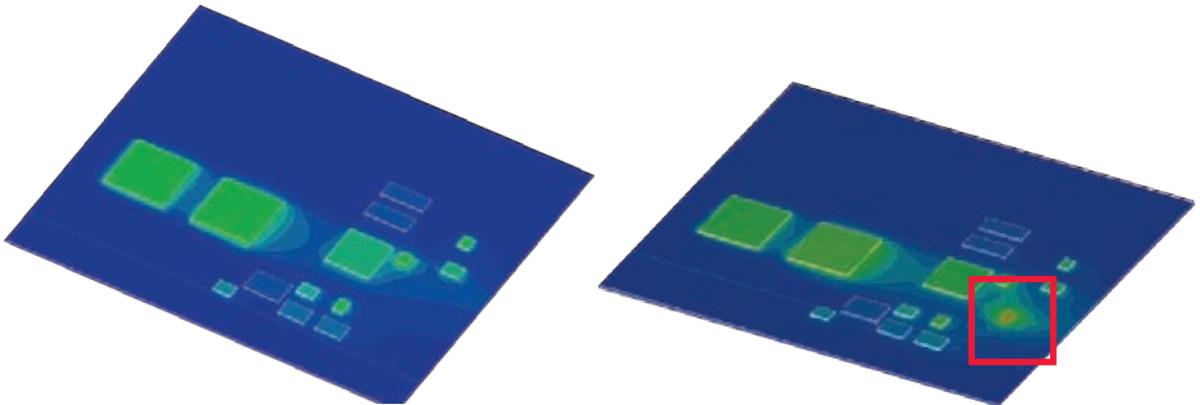
ANSYS Icepak software has been used by electronics engineers as the best-in-class thermal management tool for many years. Coupling Slwave technology with thermal simulations adds an unprecedented fidelity that allows engineers to make more-informed decisions on the design based on increased awareness of power dissipation, current constraints and thermal hot-spot locations. The following example shows how a bad design could



Color-coded vector plot of current from Slwave software shows high-density “current crowding” in red near the single via that connects the top layer of the circuit board to the main power supply plane for all semiconductor devices.

have passed quality control if not for the use of electro-thermal cosimulation.

The example board contains complex interconnections of trace routings, power/ground planes, discrete components (resistors, capacitors, inductors, etc.) and landing pads for soldering ICs and other semiconductor packages to the board. Power to these ICs and semiconductor packages is provided by a voltage regulator module (VRM), with dc current flowing from the VRM through a single via to a main supply plane where the current spreads out to feed all the semiconductor devices. Concentration of current at the single via is high, resulting in considerable resistive loss at that point.



ANSYS Icepak simulation (left) performed without the heat distribution input from Slwave software does not show the hot spot. Temperatures approaching 110 degrees C were revealed using the two programs coupled in a cosimulation (right).

Slwave software was used to study current distribution throughout this circuit board, with the design imported into the tool from its original third-party layout environment. By using Slwave technology, engineers could visualize the current crowding at the single via. What they could not see from this simulation alone was the thermal hot-spot in this region and the exact temperature rise caused by the electrical current flow through the via.

For the temperature implications to be determined, the heat distribution output from the Slwave simulation

was read into the ANSYS Icepak model for thermal simulation. The combination of the tools determined the excessive temperature rise in this region and allowed for this design flaw to be accurately determined and corrected by engineers. This was all performed in the early stages of design, before prototype mockup boards were fabricated. ■

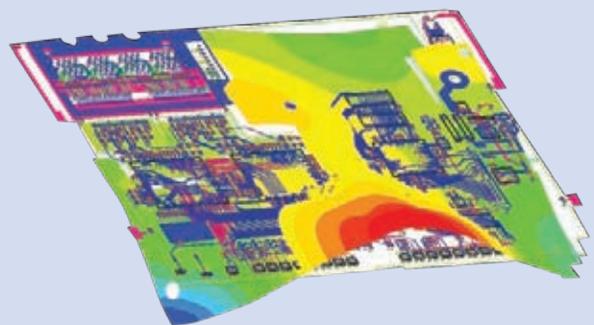
The authors acknowledge contributions to this article from Kapil Sahu and Birenda David of ANSYS India.

PCB Signal and Power Integrity

Slwave software from ANSYS is an electromagnetic field solver that performs broadband signal- and power-integrity analysis along with dc voltage and current analysis for complete printed circuit boards and integrated circuit packages. Whereas 3-D electromagnetic solvers that require tremendous levels of compute resources are practical in studying only portions of a circuit board, the Slwave product provides a highly efficient and accurate full-wave solution for an entire complex board using a 2-D finite element method technique that takes into account:

- All discrete components on the board, such as resistors, inductors, capacitors and ferrites
- Resonances that occur between internal planes
- Return path of traces that may traverse the entire board
- All trace and plane coupling relevant to the simulation

Regarding joule heating, Slwave software can perform a dc IR drop simulation that can solve for the current path of the planes. For a given voltage source



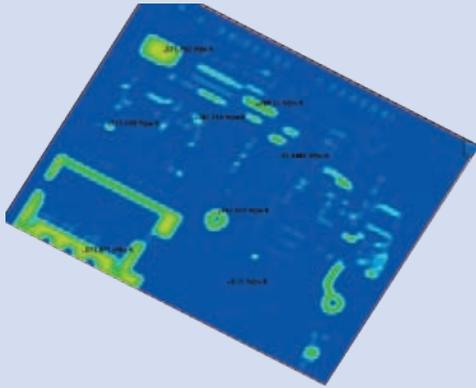
Resonant mode simulation with Slwave software highlights the locations of standing waves and indicates components that might be coupling into the modes.

point and a current draw location, the Slwave product can solve the exact path of the current as it travels from source to sink and can calculate the voltage drop on the planes due to resistive losses. This insight is important from a thermal perspective because it provides valuable insight into high-current areas that would create the most resistive losses and, thus, translate into the highest regions of heat dissipation. The ability to look at the perforated power and ground rails provides a level of fidelity that could not be coupled with thermal design in the past.

Thermal Management of Electronics Packages

ANSYS Icepak fluid flow software is used by electronics design teams worldwide for a variety of reasons, including:

- Native as well as neutral MCAD model import capabilities
- Capability to import electronics layout files such as Gerber, Cadence® and IDF format files



ANSYS Icepak software has the capability to determine effective conductivity of copper layers on a PCB based on metal content and directionality on the board.

- Productivity enhancement through its library for IC package models
- Macros for heat sink and thermoelectric coolers
- User-friendly models for fans, blowers and attach materials

The capabilities architected and built into ANSYS Icepak technology over a decade of close industry collaboration form the foundation for the next generation of multiphysics-based codesign methodologies. In the study of thermal behavior of a typical circuit board, this tool has the capability to read in trace geometry for detailed analysis of both trace and plane layers, for example, and also to identify the localized distribution of directional conductivity based on a board metallization layout. Accurate as well as computationally practical, this conductivity estimation technology forms the basis for the next generation of multiphysics-based board-level electro-thermal codesign between SIwave and ANSYS Icepak software.

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