Multiphysics Simulation of a Printed Circuit Board

When evaluating printed circuit board (PCB) designs, engineers must balance the requirements of multiple physics disciplines in optimizing PCB reliability. R&D teams must closely study three broad areas of product reliability — electrical, thermal and mechanical — to produce PCB designs that contribute to long service life and reduced product failure. You can use ANSYS software in an integrated fashion to examine the overall reliability of a printed circuit board, simulating individual physical phenomena as well as the interaction between physics disciplines to improve overall product performance.

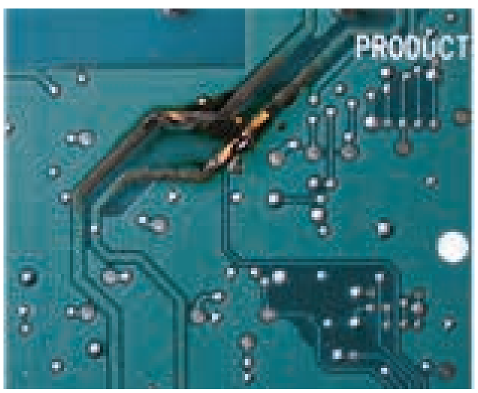

Figure 1. Fused electronic trace due to current overload. A multiphysics simulation can evaluate the combined electrical and thermal effects that lead to this failure.

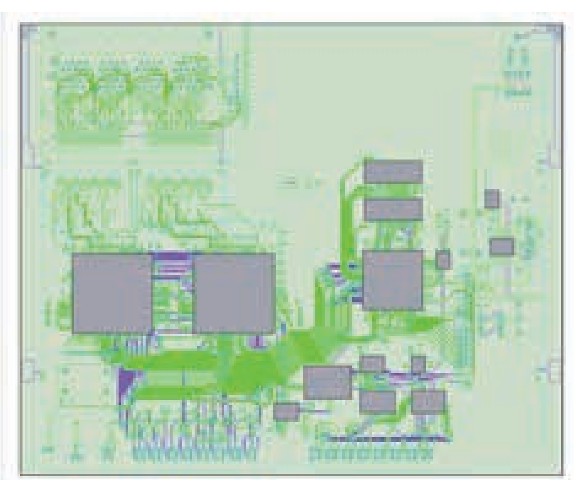

Figure 2. In PCB design, engineers must evaluate a design's electrical, thermal and mechanical reliability to ensure a long service life and no premature failures.

Products
ANSYS® SIwave™, ANSYS Icepak®, ANSYS Mechanical™

Keywords
PCB design, DC IR drop, thermal dissipation, thermomechanical stress

Description
When designing a printed circuit board for reliability, there are three broad areas to consider: electrical, thermal and mechanical reliability. Evaluation of electrical reliability requires power- and signal-integrity analysis to minimize crosstalk and evaluate the board's power integrity. Addressing thermal reliability calls for thermal simulation to evaluate temperatures of the board and associated components, ensuring that the device operates within an allowable temperature range. And mechanical reliability requires a thermal–stress simulation to evaluate thermal and mechanical stresses in the board along with solder joints between board and components. In addition to performing individual physics simulations, engineers must consider the interaction between physics disciplines, which requires a multiphysics simulation approach. This method provides a holistic view of overall reliability of PCB design.

The first step is to compute a DC solution with ANSYS SIwave. The DC solution provides information on power delivery for board components; you can use it to determine if the voltage regulator supplies proper DC voltage to all active components on the PCB. This solution also offers information on current density, which can be used to determine areas where board or via damage may occur as a result of current overload. The DC solution provides power dissipation information for all metal layers of the board, data that can be exported to ANSYS Icepak for PCB thermal evaluation.

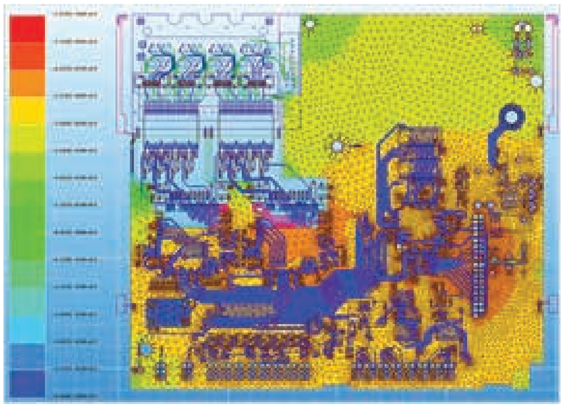

Figure 3. DC solution from SIwave. The solution provides current density, which can be used to determine areas of high current density where board or via damage may occur as a result of current overload.

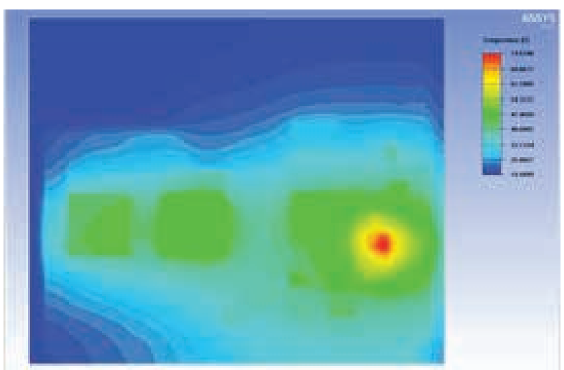

Figure 4. Thermal solution from ANSYS Icepak. Temperature results indicate a hot spot on the board that is caused by power dissipation in the metal trace layers. This hot spot could not be detected without a multiphysics simulation.

The next step is to conduct a thermal simulation with ANSYS Icepak, which provides information on the thermal reliability of the board and components. One advantage of using SIwave and Icepak together is that both products can work with the same EDA layout information for electronic traces and vias. SIwave uses EDA layout information for electrical layout, whereas Icepak uses trace and via information to evaluate orthotropic thermal conductivity of the printed circuit board. Accurate thermal conductivity for the board is a prerequisite for accurate thermal simulation results, as the majority of heat from board components is conducted through and/or dissipated via convection or radiation from the board itself.

Thermal simulation with Icepak accounts for power dissipation of components — as well as power dissipation in the metal layers of the printed circuit board computed with SIwave. Temperature dependence of electrical properties in SIwave can be accounted for by an iterative solution, in which multiple iterations between the DC solution and the thermal solution are used to obtain a converged power dissipation and temperature profile in the board. These iterations account for temperature dependence of electrical resistivity in the DC solution along with resultant temperature dependence in power dissipation of the metal layers. Accounting for multiphysics effects improves the accuracy of both electrical and thermal simulations, providing an increased understanding of both electrical and thermal performance of the PCB.

Once the power dissipation and temperature results have converged using SIwave and Icepak, the thermal solution can be used to determine if the board and component temperatures are within allowable ranges. The thermal solution provides assistance in determining various cooling options for PCB and components, such as selecting a fan or including a heat sink on a critical component. In practice, the lower the temperature in the board and components, the fewer problems there are with thermally induced failure mechanisms in the device.

You can export the converged temperatures to ANSYS Mechanical to evaluate thermal and mechanical stresses in the board and associated components. The ANSYS Workbench™ environment provides a simple mechanism to map the temperature field from Icepak to a Mechanical simulation across a dissimilar mesh interface. The thermal–stress simulation provides information on the mechanical reliability of the board and components. It enables evaluation of thermal deformation and thermal stress from the temperature field; it also can be used to evaluate thermal fatigue in solder joints from temperature cycling. Design decisions about board supports — such as connection locations, evaluating stiffeners, component placement and clamping loads — can all be evaluated with Mechanical simulations. Reducing mechanical stresses from large temperature variations leads to a reduced number of thermally induced fatigue failures.

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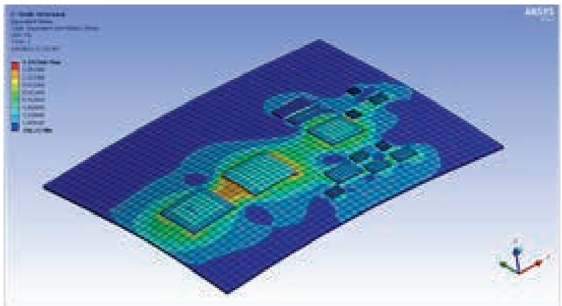

Figure 5. Thermal–stress solution using ANSYS Mechanical. Stress results consider the thermal gradients and coefficient of thermal expansion mismatch between the printed circuit board and components.

Summary

In this example, ANSYS SIwave, ANSYS Icepak and ANSYS Mechanical simulate the multiphysics environment of a printed circuit board, evaluating electrical, thermal and mechanical effects in an integrated multiphysics analysis process. SIwave evaluates the DC IR drop for the board, Icepak analyzes thermal performance of the board and components based on component power and resistive heating of the electronic traces, and Mechanical evaluates mechanical performance by determining thermal stresses from temperature gradients and coefficient of thermal expansion mismatch between board and components.

Multiphysics simulation from ANSYS offers an unequaled level of accuracy for evaluating PCB design by incorporating electrical, thermal and mechanical effects into an integrated solution. Multiphysics simulation improves PCB reliability by accounting for the effects of individual physics along with the interaction between physics, leading to an overall longer product service life.

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