Optimization of Thermal/EMI Solution Reduces Component Design Time from Weeks to Days

Due to the reduction in electronics form factors and the need to include more and more components into each device, many original equipment manufacturers (OEMs) are looking to combine electromagnetic interference (EMI) and thermal solutions into single assemblies. This adds to the complexity of the thermal design process. It creates a need for multiple layers of thermal interface materials whose performance interacts with each other.

Laird Performance Materials recently worked with an OEM customer to design a combined EMI/thermal solution. Laird typically calls this a "multi-functional solution" incorporated as a single manufacturing process. The simulation showed that the package temperature of the heat source exceeded the maximum value of 90C. Laird chose to set up an optimization that explored the entire design space which had been defined and iterated to an optimized design. The subsequent optimization reduced the package temperature to an acceptable level 13C below the original design. The design was optimized in only a few days compared to the many weeks which would have been required using the normal one-iteration-at-a-time method.

Laird designs and manufactures performance-critical products for wireless and other advanced electronics applications. The company is a global market leader in electromagnetic interference (EMI) shielding or absorption products and thermal transfer materials. Built upon advancements in the material sciences, Laird both enables and protects high-performance electronics for a wide variety of industries including IT/telecommunication, medical, automotive, consumer electronics, military/aerospace and more.

Laird provides multi-compartment shields to cover multiple-board areas simultaneously. Some of Laird's popular combination shields include the microwave absorber board-level shield – a combination of a microwave absorber with board-level shielding that can absorb or suppress high-frequency interference, enabling the board to be more effective at high frequencies. To address applications where heat needs to be removed and board-level shielding is also required, Laird incorporates thermal interface materials with board-level shields. Adding a gap filler material with high thermal conductivity between the electronic component and board-level shield cools the component by transferring heat efficiently to the shield, which acts as a heat spreader.

Complex combination EMI and thermal solution

Laird developed a custom solution consisting of a printed circuit board with a heat source and an EMI shield consisting of a metal plate that also serves as a heat spreader. The heat source is separated from the EMI shield by a layer of thermal interface material. A heat sink is mounted to the EMI shield and separated from it by another layer of thermal interface material. The complexity of the design results increases the number of design parameters which in turn exponentially increases the number of design alternatives that must be considered to deliver an optimized solution.

The traditional approach to resolving this challenge would have been to use intuition and hand calculations to develop the initial design concept. Then a prototype would have been built and tested to evaluate temperatures at key points. Chances are the first design would not have met requirements so it would have been necessary to embark upon an iterative process of modifying and testing the prototype until the design requirements were met. The difficulty of this process would have been increased by the number of design parameters. Using this method, it could have taken months to find an acceptable solution and years to find the optimal solution.

Using simulation replaces physical prototype

Laird developed the initial design concept using rules of thumb developed from earlier projects. Instead of building a physical prototype, however, designers simulated the initial concept design using thermal simulation software. Thermal simulation allowed him to accurately predict the thermal performance of the initial and subsequent designs without having to build and test a prototype. The thermal simulation software was easy to use and could simulate nearly any type of thermal solution. Another of the software was that most customers use it for thermal simulation. They have confidence in the simulation results and models can be shared easily.

Laird used a modeling feature application to model some of the components of the model such as the PCB and the heat sink without having to create their full geometry. The advantage of using the modeling feature instead of defining the board geometrically is that the part can be defined much faster by filling in the blanks in the form-based menu system.

Laird created the part by defining the length and width and each layer of the board. The percentage of copper and dielectric was specified for each layer. Then the heat sources and heat sink were added. The use of modeling feature also reduces the complexity of the model and hence the time required to perform the simulation.

The simulation of the initial design showed that that the junction temperature of the heat sources was well above the 90C limit. Rather than randomly evaluating alternative designs, Laird took advantage of the thermal simulation software's capabilities that automate the process of optimizing the design of a heatsink or any other aspect of thermal management automatically. It defined which design parameters could be varied, in this case the number of heat sink fins, fin thickness, heat sink base thickness and thermal resistance of the two thermal interface materials. Each of the design parameters could vary by +/- 50% of the values in the initial design concepts.

Design goals were defined in the form of a cost function by specifying absolute limits for several design variables and indicating that the goal of the optimization was to minimize the junction temperature. In general, the cost function may be a single, simple value such as the junction temperature of a certain component or a complex linear combination of values including weighting.

Iterating to an optimized design

Laird configured the optimization run so that if the optimum for any of the variables was at the maximum or minimum, then additional optimization runs were performed starting from the previous optimum values. If none of the variables were optimized at their maximum values, the software was configured to perform additional runs over a small range.

The automatic sequential optimization capabilities of thermal simulation software then automatically created and ran the required number of simulations to explore the entire design space. Instead of running all possible combinations of values in order to explore the whole design envelope, which would have taken a great deal of CPU time, the software automatically created and ran the number of simulations needed to explore the entire design space in the most cost-effective way.

As an alternative to automatic sequential optimization, a design of experiments (DoE) can be constructed that will automatically analyze the full range of all possible combinations of parametric variations. Whichever approach is used, the models generated during the optimization process can be solved on a distributed network of computers using the unique “volunteer” solution technology.

Temperature profiling of a PCB with a cooling solution

The thermal simulation software then generated a response surface showing the value of the design goals for all the combinations of variables that were run. Laird viewed the response surface in 3D to visualize the sensitivity of the cost function to changes in each design parameter. Viewing the response surface helped designers understand the sensitivity of the various local optimum values of the design parameters with respect to manufacturing variation. In many cases, it may make sense to use a combination of design parameters that provides slightly lower performance if its sensitivity to variation is lower. A more robust design generally means higher manufacturing quality and lower costs.

Final product exceeds customer expectations

Laird picked out the preferred optimum value, saved it as a new project file and then solved the file to confirm the global optimum. The optimized routine produced a design that substantially reduced junction temperatures while meeting all other design constraints.

Laird technicians then built and tested a prototype of the optimized design. The technicians measured the package temperature and used the junction-to-case thermal resistance values provided by the customer to estimate junction temperature.

The thermal performance of the prototype matched the simulation predictions closely. The thermal/EMI solution is now in production and the feedback provided by the customer is very positive.