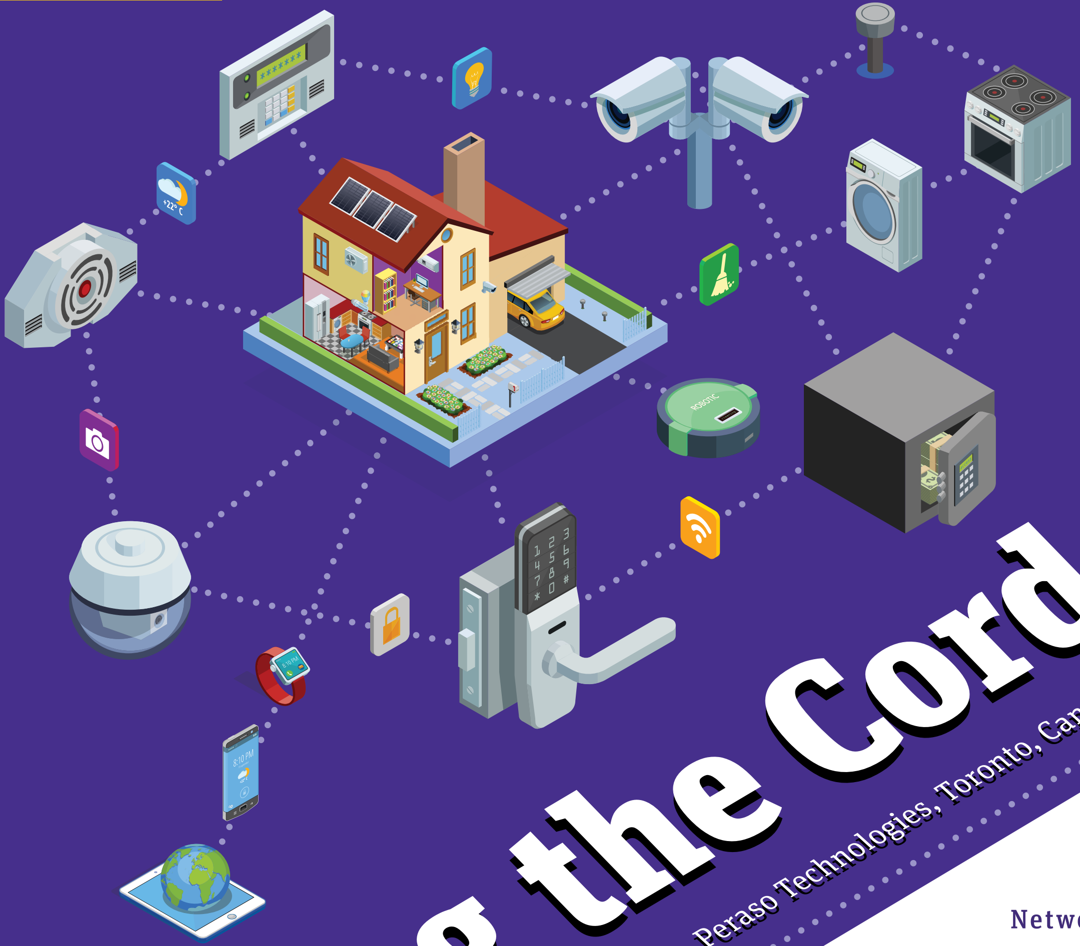


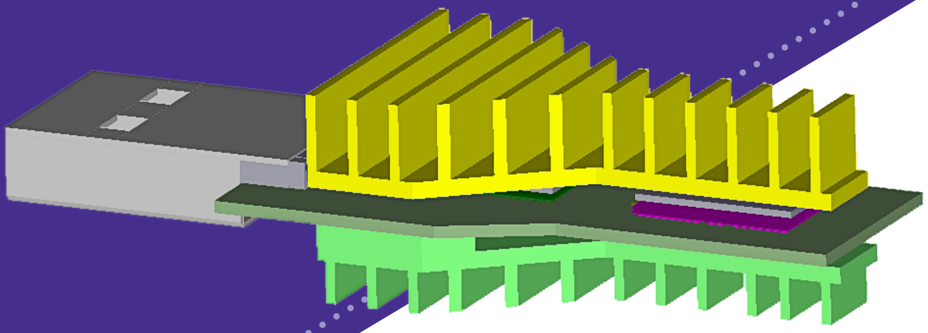
Cutting the Cords

By **Dori Itzhaki**, IC Package & Board Design Expert, Peraso Technologies, Toronto, Canada

Networking experts predict that, by 2021, 66 percent of all internet traffic will be used for high-throughput services such as wireless docking, video streaming, cloud backup and virtual reality. Peraso Technologies enables users to cut the cord and go wireless by providing chipsets based on the emerging 802.11ad (WiGig) standard that delivers high-speed wireless throughput in a USB 3.0 stick form factor. Peraso engineers used Ansys simulation software to solve thermal problems associated with packing high-power transmitters into a tiny enclosure.

Early design of enclosure modeled in Ansys SpaceClaim

TODAY'S STATE-OF-THE-ART HIGH-SPEED DATA INTERFACES, such as docking stations, 4K video streaming, virtual reality headsets and other similar products, commonly require wired connections to avoid data bottlenecks. The multigigabit speed of Peraso's W120 WiGig chipset enables users with a SuperSpeed USB 3.0 port to simply plug in a USB stick to achieve multigigabit speeds that are fast enough so that users can cut the cord on high-speed interconnect applications. One of the greatest challenges in designing a USB 3.0 WiGig adapter based on the W120 chipset was dissipating the heat generated by the adapter within a tiny enclosure that is similar in size to a typical thumb drive. Peraso engineers overcame this challenge using Ansys multiphysics simulation to accurately predict temperature and heat flow at every point in the adapter as they iterated its design. Simulation reduced the time required for thermal design by two-thirds.



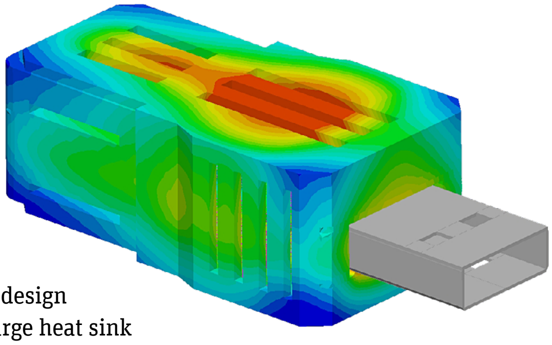
Ansys Icepak model of interior components of the adapter shows: top heatsink (yellow) connected to 115 C-rated components, bottom heatsink (light green) connected to PCB, one of 115 C-rated components (red), PCB (green) and USB connector (gray).

THERMAL DESIGN CHALLENGE

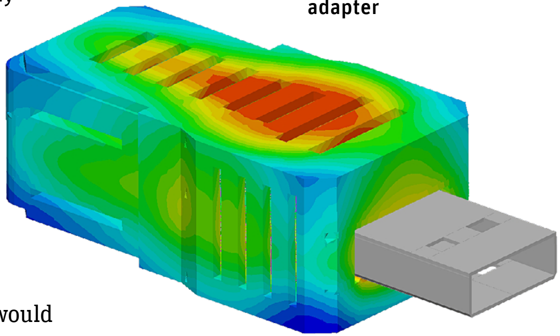
WiGig is a new wireless networking standard from the Wi-Fi Alliance that adds a third 60 GHz band to the existing 2.4 GHz and 5 GHz bands of Wi-Fi to enable extremely high data rates, lower latency and dynamic session transfer in multiband devices. Peraso's new W120 chipset provides a high-speed USB 3.0 to WiGig solution that enables blazing fast high-throughput wireless connectivity for a host of applications that require more bandwidth than Wi-Fi can deliver. In designing a complementary USB 3.0 WiGig adapter, the conflicting requirements for high-power transmitters and a compact, cost-effective enclosure created a thermal challenge for the system's designers.

The W120 WiGig adapter includes two main chips that dissipate considerable heat and a number of other active and passive components, all mounted on a printed circuit board (PCB) with traces that produce Joule heating effects. The two main chips that dissipate most of the heat in the adapter are rated to 115 C junction temperature, while the other components on the PCB are only rated to 85 C. Because heat dissipation in a small enclosure is very difficult to achieve, the most cost-effective way to cool the adapter would be to maintain the chips and PCB near their respective maximum temperatures. Engineers explored several thermal design options, and concluded that their solution should employ a large heat sink connected to the two chips but not to the PCB, and a smaller heat sink connected to the PCB but not to the two chips.

In creating the thermal design, engineers needed to identify the sweet spot, where just enough heat was removed from the chips to allow them to perform at acceptable levels while keeping the PCB at a cooler temperature. This entire structure had to be enclosed in a case with limited openings. The case interferes with free air flow, so optimizing its shape was imperative to achieving efficient and effective thermal cooling. Had engineers used traditional build-and-test methods, they would have had to guess at how heat was transmitted through the adapter. In particular, their inability to measure airflow inside the unit would have made it very difficult to determine how to fix problems identified in physical testing.

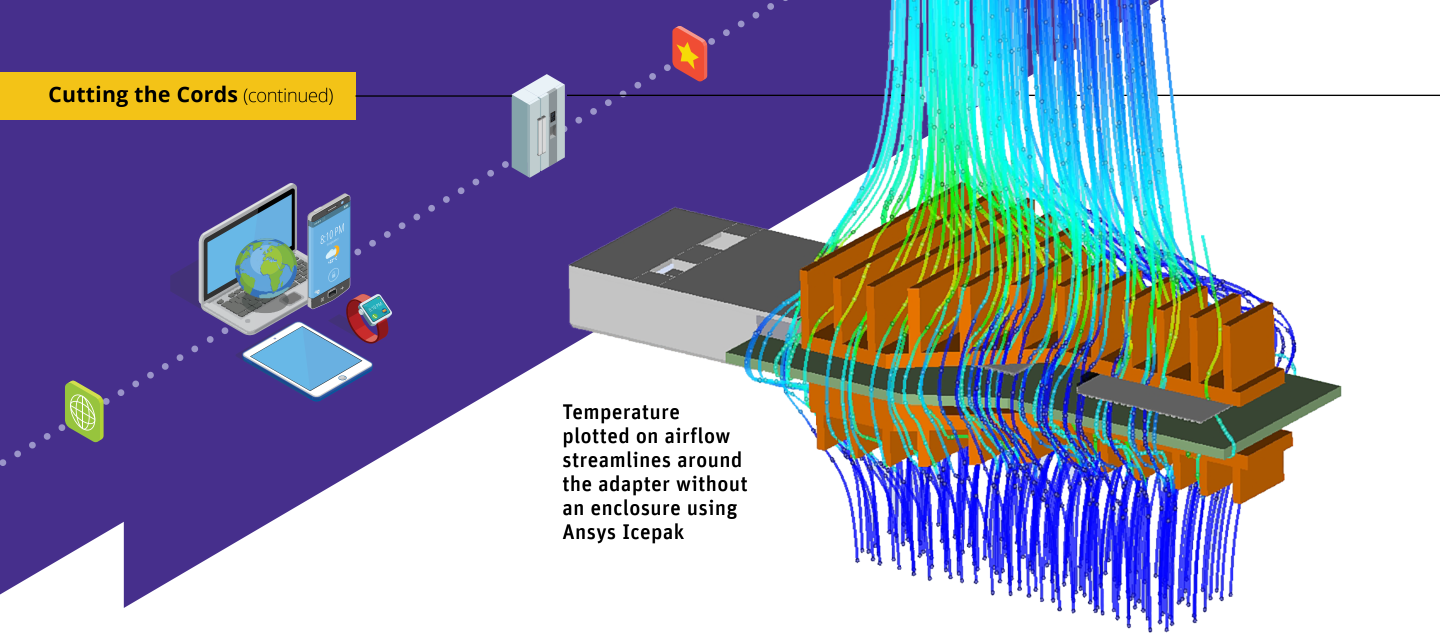


Temperature of the adapter with enclosure openings oriented along length of adapter



Temperature of the adapter with enclosure openings oriented along width of adapter

Ansys SIwave to Icepak Coupling
ansys.com/siwave-icepak



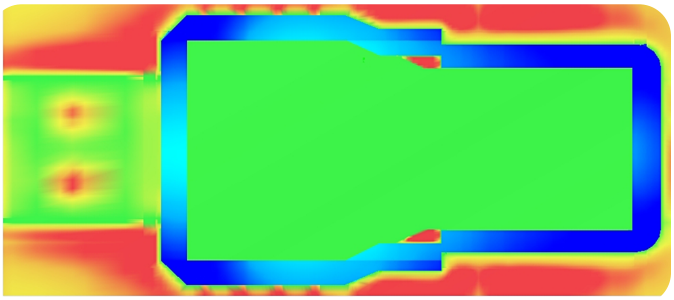
Temperature plotted on airflow streamlines around the adapter without an enclosure using Ansys Icepak

SIMULATING TEMPERATURE THROUGHOUT THE ADAPTER

To address these challenges, the team used Ansys SIwave electromagnetic field solver to capture the Joule heating effects. The resulting heat map was transferred to the Ansys Icepak thermal analysis tool where the current flow heat was combined with all the other thermal effects for a comprehensive thermal analysis. This enabled Peraso engineers to accurately predict heat distribution and temperature at every point in the inner electronics of the adapter. They also modeled the electronic components in Icepak using predefined building blocks and defined the active components as heat sources. To design the heat sink's structure and the enclosure for the adapter, they created the geometry of an initial design using Ansys SpaceClaim and imported it into the Icepak module. Icepak used all the information revealed by the electronics simulation to evaluate the orthotropic thermal conductivity of the PCB and compute the temperature at every point in the solution domain.

> **“Simulation enables engineers to explore thermal management solutions in much less time than was possible in the past.”**

The simulation results showed the temperature of the components rated at 85 C was too high. The problem was largely caused by heat leaking from the two main components through the PCB to the 85 C–rated components. To tackle this problem, they modified the design of the board to balance the thermal conductivity between the top and bottom layers and steer the heat dissipation in the right direction. They also changed the ratio of the size of the two heat sinks. Several iterations were required to achieve the right heat transfer balance between the devices and the PCB.



Temperature plotted across cross section of adapter aligned with PCB showing hot spots (red) where flow is constricted by narrow gaps between PCB and enclosure

After the right balance was found, the engineers added the enclosure element into the design. The enclosure negatively affected the heat flow around the board and heat sinks, so they had to provide some openings in the enclosure. The engineers focused on finding the right configuration of openings in the enclosure that would create minimal disturbance to the airflow through the adapter and reduce the loss in the convective heat transfer from the heat sinks to ambient. The overall area of the openings in the enclosure is limited by structural considerations, but engineers had considerable flexibility in positioning these openings.

ITERATING TO AN OPTIMIZED DESIGN

To continue their thermal optimization, the team modified the design of the enclosure numerous times in SpaceClaim and reran the simulation, using the simulation results to guide them as they iterated toward an optimized design. The advantage of using SpaceClaim is that the user can push, pull and rotate faces on solid models while all of the nearby geometry adjusts in real time without having to consider parametric constraints. To understand how air naturally flowed around the electronic components, the engineers simulated the electronics without an enclosure. Then they created a new enclosure design in SpaceClaim to position the openings in the areas where airflow was the highest. They simulated the new design, and the results showed improved heat dissipation.

Engineers wondered whether orienting the openings along the length or along the width of the adapter would be more effective. So they created two versions of the enclosure, with the openings oriented widthwise in one and lengthwise in the other, and ran a new simulation on each. The results showed that orienting the openings along the length of the adapter was more effective. The team created additional design iterations to evaluate other opening configurations, reducing the temperature of the PCB to the point where it nearly met the specification. Engineers were briefly stumped as to how to get over the finish line when one of them had the idea of viewing flow velocity over a cross section aligned with the PCB. The results showed that flow was constricted in a small area near where the PCB came close to bumping up against the enclosure. They reduced the size of the PCB slightly to free up flow in this area, and the temperature of the PCB dropped to the level needed to meet the spec.

> **“Engineers used Ansys multiphysics simulation to accurately predict temperature and flow at every point in the adapter as they iterated its design.”**

This application provides an excellent example of how simulation enables engineers to explore thermal management solutions in much less time than was possible in the past when physical testing was the primary design tool. Physical testing provides temperature measurements at a few key points, which is enough to determine the effectiveness of a proposed design, but it usually provides little guidance on how the design needs to change to meet the spec. Engineers estimate that with physical testing alone it would have taken three to six months to meet the temperature spec on the USB-3 adapter. Using Ansys simulation tools, on the other hand, provided temperatures, flow velocities and pressure at every point in the solution domain. This diagnostic information guided engineers in quickly improving the thermal design of the adapter. As a result, in just one month engineers were able to meet the design specification by reducing the temperature of the PCB by 7 degrees.