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Solving tablet and mobile device thermal design challenges

Simcenter thermal simulation and test solutions help improve thermal management

Executive summary

The growth of the tablet market is reflected in the continued decline of the personal computer market, with consumers generally choosing to replace their laptops with tablets rather than purchasing both.[1] Cheaper prices and a wide range of form factors and sizes have resulted in manufacturers designing devices that are slimmer, sleeker and more compact than ever before.

The thermal design of next-generation handheld devices must address both comfortable surface touch temperatures and maximum temperature limitations of critical internal components while also meeting aggressive industrial design requirements. This paper discusses the challenges in meeting these requirements in tablet designs.

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Thermal models of tablets were created using Simcenter™ Flotherm™ XT software to help understand the maximum allowable power dissipation under various operating conditions. The models were also used to conduct parametric studies to determine the best way to move heat from the internal components out to the case of the tablet where it can be dissipated.

Maximum power dissipation

Handheld devices are increasingly capable of running applications that formerly required laptop and desktop computers. The requirement that these devices provide better performance with a smaller form factor presents significant challenges, especially when one considers that passive cooling is also a requirement. Several studies have focused on the cooling challenges of hand-held devices.[2-6]

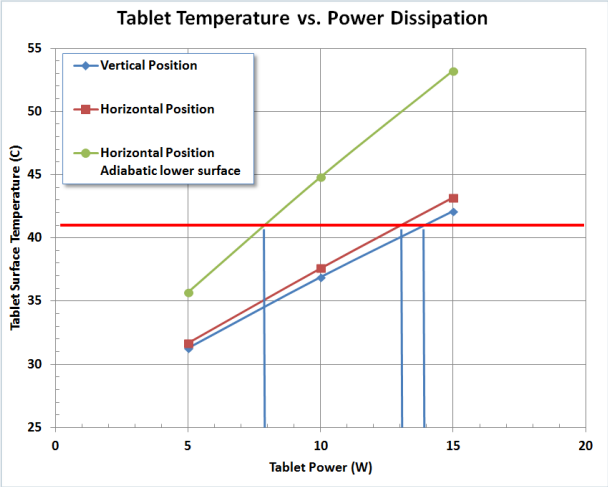


Figure 1: Total power dissipation removed by passive cooling of a tablet

The maximum possible power dissipation by natural convection and radiation has been calculated for this study and is shown in figure 1. With a 25°C ambient condition at sea level, the maximum total power dissipation was calculated with a requirement that the surface temperature not exceed a touch temperature of 41°C. This is the maximum aluminum enclosure comfort touch temperature.[7]

The theoretical maximum total power dissipation is 13.9 watts when the device is suspended vertically in midair with conduction and radiation occurring from all surfaces as shown in figure 2. When the device is horizontal, the maximum dissipation falls to 13.1 watts. When the device is placed on a horizontal adiabatic surface, heat transfer occurs from the sides and front surface only and the maximum power dissipation is reduced to 7.9 watts as shown in figure 3. This condition occurs when the user places the tablet on a blanket or pillow, effectively blocking heat transfer from the back surface. These values establish bounds for the maximum amount of heat that can be dissipated by the tablet for different orientations in still air.

In order to calculate the total power dissipation, the following assumptions were made: a typical tablet size of 180 mm by 240 mm and an ideal condition of uniform surface temperature. With a conservative assumption of a surface emissivity of 0.8, the radiant heat transfer accounts for more than half of the total power dissipation at an ambient temperature of 25°C.

In order to achieve a 41°C touch temperature, design parameters need to be considered carefully. It is important to design the tablet to be as isothermal as possible to maximize the amount of heat transfer to the surroundings. All surface areas of the tablet are as far above ambient temperature as possible to maximize heat transfer without exceeding the maximum allowable touch temperature. When a surface is no longer available for heat transfer, such as when the tablet is placed on a blanket, the amount of power that can be dissipated while staying under the maximum touch temperature drops significantly since heat transfer is effectively blocked from the back surface.

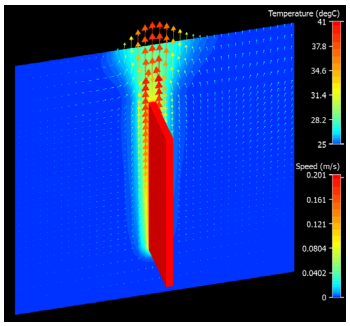


Figure 2: 41°C isothermal tablet in vertical position

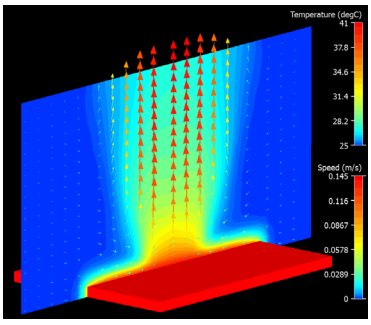


Figure 3: 41°C isothermal tablet in horizontal position on an adiabatic surface

The value of numerical models

In order to analyze the impact of different thermal management techniques, a detailed computational fluid dynamics (CFD) thermal model was constructed using Simcenter Flotherm. Since the actual thermal characterization data of the main processor in the tablet may not be known, the thermal characteristics of the processor can be measured with a high degree of accuracy using Simcenter T3STER™ hardware to determine the thermal resistance from the processor IC to the case and the PCB. This allows accurate capture of heat flow from the top and bottom of the processor. The thermal model of the processor that was generated using Simcenter T3STER can be directly dropped into the tablet thermal model in Simcenter Flotherm. The results of a detailed thermal model of the interior of a tablet are shown in figure 4.

The automatic adaptive meshing in Simcenter Flotherm XT follows the small surface details of the components to accurately capture convective and radiant heat transfer from these surfaces.

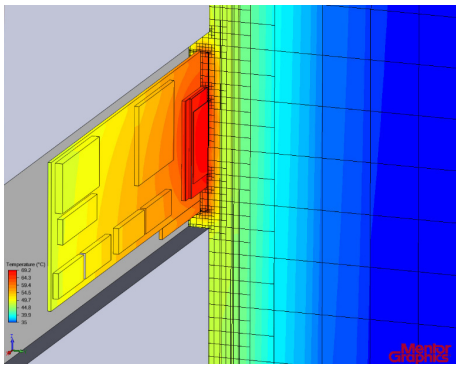


Figure 4: Detailed model of the PCB created in Simcenter Flotherm XT

Hot spot temperature reduction

Since the goal is to keep the touch temperature at or below 41°C, determining the effect of high-conductivity heat spreaders will have a major impact on the design. Some parametric studies were run to determine the effect of making the back side of the case with materials of varying thermal conductivity. The results are shown in figure 5 and summarized graphically in figure 6. This study assumes the same power dissipation for each simulation. The only parameter that was changed is the thermal conductivity of the case. As a reference point, typical thermal conductivity of most plastics is in the range of 0.2 Watts per meter-Kelvin (W/mK) while aluminum approaches 200 W/mK.

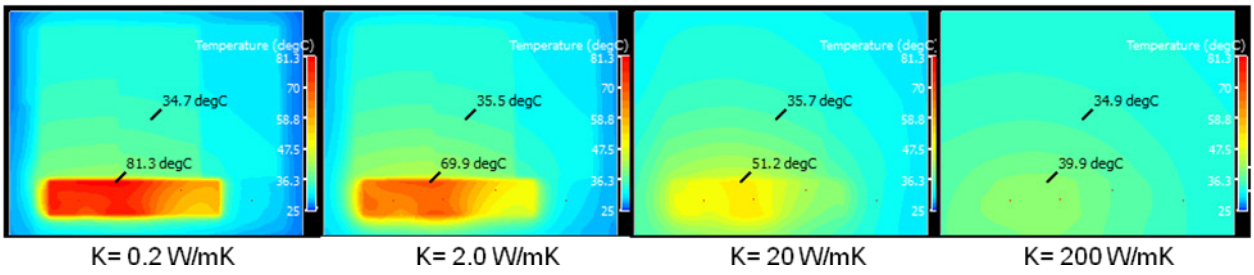


Figure 5: Back side hot spot temperature change as a function of case thermal conductivity

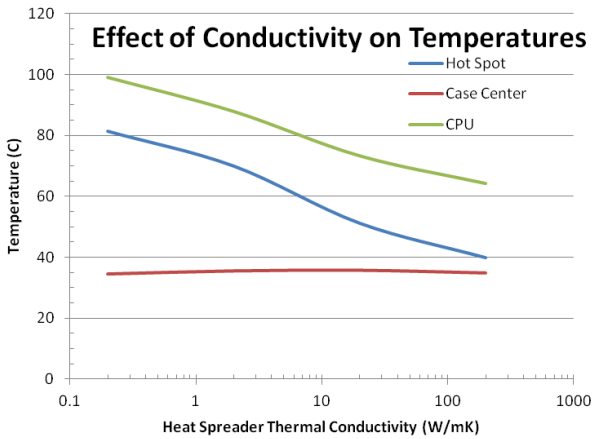


Figure 6: Effect of thermal conductivity of the case on temperatures

Aluminum is about 1,000 times more thermally conductive than plastic. Hot spot temperature reduction can be achieved by either providing a high-conductivity heat spreader inside the case of the tablet or by making the case itself out of high-conductivity material. The maximum touch temperature is also a function of the conductivity of the case. As the conductivity goes down the maximum comfortable touch temperature goes up.

As an example, if the case is made of plastic with a thermal conductivity in the range of 0.2 W/mK, the case temperature that the user senses appears to be cooler than that of an aluminum case since the low thermal conductivity of the plastic results in less heat being conducted between the case and the skin. Since the surface area of the case is large in relation to the thickness of the plastic, heat transfer to the air is not reduced significantly over that of an aluminum case. This of course assumes that the heat is spread on the inside of the plastic case using a high-conductivity aluminum plate or a graphite sheet.

Deriving a thermal model of a processor

When building a thermal model of a tablet, the thermal characteristics of the processor are not always known with a high degree of accuracy. Data sheets from the suppliers of thermal interface materials may not accurately reflect the thermal resistance of the interface material and the wetting properties of the material between the processor chip or lid and the heat spreader.

To overcome this limitation and get an accurate thermal model of the processor, Simcenter T3STER was used to determine the thermal resistance from the processor IC to the lid or heat spreader and the PCB. Simcenter T3STER can perform a dynamic thermal characterization of the thermal resistance paths of a packaged semiconductor device.

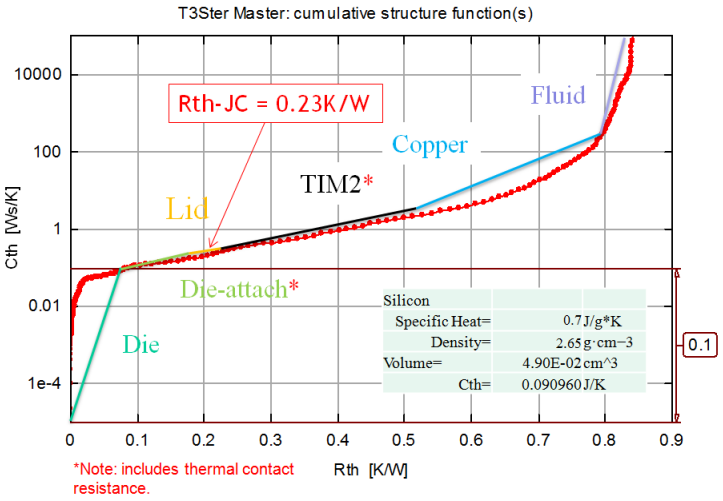


Figure 7: The cumulative structure function measured for the processor and lid using Simcenter T3STER

The transient temperature response of the die is recorded as a function of a step input in power to the die and a structure function is derived from the transient temperature response that characterizes the thermal resistance of all the materials in the thermal path. Figure 7 shows the structure function derived for a processor using Simcenter T3STER. The thermal resistance from junction to case is measured at 0.23 Kelvin per Watt (K/W) using this technique.

This thermal model of the processor package is then applied in the CFD simulation and numerical experiments can be run to determine the change in processor junction temperature as other elements in the thermal path (such as heat spreader materials and dimensions, air gap thickness between the heat spreader and back case and case materials) are changed.

Summary

The maximum power dissipation of the internal components is not only governed by the size of the tablet but is a strong function of how well that heat is spread internally to reduce hot-spot temperatures. Few engineers realize the importance of radiation in dissipating the heat from the exposed surfaces of a tablet; the importance of radiation in the thermal design becomes apparent only when precise calculations are made. If the emissivities of the various surfaces are high, more than half of the heat transfer to the surroundings is due to radiation. Overall heat transfer is maximized by reducing hot-spot temperatures and spreading the heat so that all surfaces are effectively providing maximum heat transfer through convection and radiation.

Building an accurate thermal model of the tablet enables the designer to rapidly test the effect of design and material changes without incurring the high cost and schedule delays of testing prototypes. A thermal model allows the thermal design engineer to investigate far more alternatives than testing on prototypes. The result is a highly engineered tablet design that better meets the expectations of the user while providing an edge over the competition. High-quality thermal models accelerate time to market and reduce development costs. With the accuracy of the latest simulation software, the intermediate step of building and testing thermal prototypes can be reduced or eliminated. The only need is final thermal verification of production prototype samples.



Figure 8: Lab setup with infrared camera, power measurement and temperature logging equipment

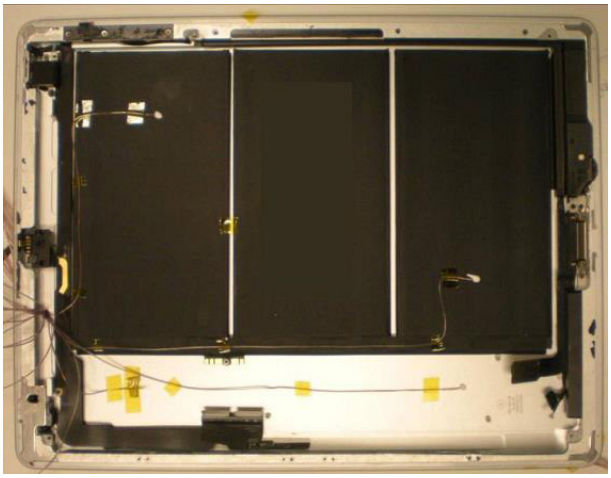


Figure 9: Tablet interior with thermocouples attached

References

1. Preliminary data from the International Data Corporation (IDC) Worldwide Quarterly Tablet Tracker
2. Brown, L., Seshadri, H., "Cool Hand Linux - Handheld Thermal Extensions," Proceedings of the Linux Symposium, Vol. 1, pp. 75 – 80, 2007
3. Gurrum, S.P., Edwards, D.R., Marchand-Golder, T., Akiyama, J., Yokoya, S., Drouard, J.F., Dahan, F., "Generic Thermal Analysis for Phone and Tablet Systems," Proceedings of IEEE Electronic Components and Technology Conference, 2012
4. Huh, Y., "Future Direction of Power Management in Mobile Devices," IEEE Asian Solid-State Circuits Conference, 2011
5. Lee, J., Gerlach, D.W., Joshi, Y.K., "Parametric Thermal Modeling of Heat Transfer in Handheld Electronic Devices," Proceedings of the 11th IEEE Intersociety Conference on Thermal and Thermomechanical Phenomena in Electronic Systems, I-THERM, pp 604-609, 2008
6. Mongia, R., Bhattacharya, A., Pokharna, H., "Skin Cooling and Other Challenges in Future Mobile Form Factor Computing Devices," *Microelectronics Journal*, Vol. 39, pp 992 – 1000, 2008
7. Berhe, M.K., "Ergonomic Temperature Limits for Handheld Electronic Devices," Proceedings of ASME InterPACK'07, Paper No. IPACK2007-33873

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