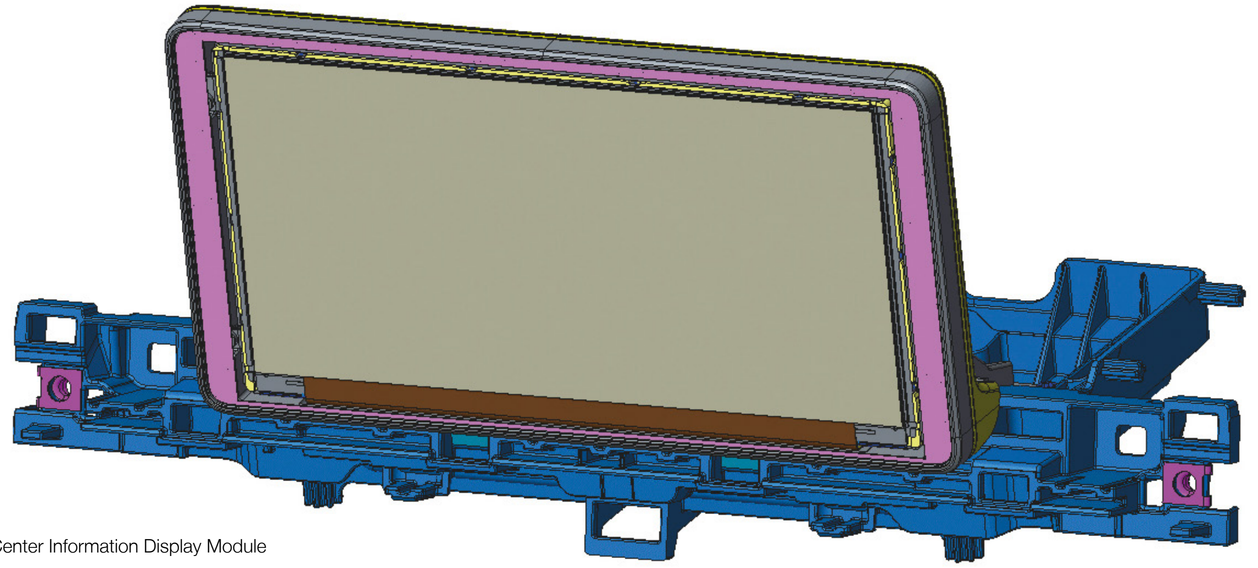

Figure 1. Center Information Display Module

Thermal Design Approach for Automotive Display Integration

By Clemens J.M. Lasance, Philips Research Emeritus, Consultant SomelikeitCool

Innolux Corporation is a world leading manufacturer of TFT-LCD displays, and supplies customers that include many of the world's leading information and consumer electronics manufacturers. Innolux Corporation employs more than 68,000 employees worldwide and is a leader in the global optoelectronics industry. Innolux actively recruit and train R&D talent to consolidate its prominent status in the industry. Innolux is striving to realize the ultimate in visual infotainment. Their unique intelligent management platform has not only enhanced the company's management capabilities, but also provides customers with prompt, accurate delivery information.

Engineers at Innolux Technology Europe B.V. were confronted with the challenge of how to solve expected thermal problems with the integration of a display-centered system into a high-end automobile. The thermal design philosophy behind the activities to be taken is the subject of this article.

A thermal model was already available based on the code CST Microwave which had an embedded thermal solver, with detailed MCAD data as input. However, there were some doubts concerning its accuracy for this application due to the fact that the code does not solve the Navier-Stokes equations. Furthermore, its radiation treatment was not well-documented and caused further concern. Hence, as a starting point for the numerical analysis the CFD code FloTHERM from Mentor Graphics would be used.

The main objective was to provide preliminary models based on the available (but not sufficiently accurate) input data to study the feasibility of the proposed complete system as a sound starting point for subsequent discussions regarding design decisions with the customer. Tests on an available prototype were performed early on to provide a first-order comparison with the numerical models. In a later stage, experimental calibration by means of dedicated tests, such as thermal resistances and thermal conductivities and component thermal data, were required due to the inaccurate thermal data delivered. One key challenge was that the system was being designed to operate in an environment where the ambient could be as high as 70°C, while the testing had to be carried out at room temperature.

The numerical models were developed as a tool for optimization: sensitivity analysis of gap pads, wall thicknesses and thermal conductivities, PCB thermal data, boundary conditions, coupling of elements to housing, decoupling LEDs from light guide, properties of the display stack, etc. These models were also to compare with dedicated tests to determine several unknowns, specifically the real-life boundary conditions and thermal interface resistances.

To get an idea of the CFD output, figure 2 depicts three screenshots for the three cross sections through the hottest point. The module is mounted vertically, showing the internal airflow, for a total dissipation of 18.5W.

Results were made available to the customer for several system test conditions, heat transfer coefficients on the external surfaces to represent natural convection, with and without radiation, various choices of gap pad, PCB data, thermal conductivity changes, etc. including component temperatures, which should be interpreted as local solder temperatures. An additional temperature rise caused by the internal thermal resistances of the components should be added, but this is only appropriate when reliable component thermal data is available.

A comparison was made between the existing model created using CST Microwave and Mentor Graphics' FloTHERM. After a series

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of trials, a reasonable match was obtained between the two codes, for identical input data and boundary conditions. However, there were a number of reasons for not continuing to proceed with CST:

- The CST model does not solve the Navier-Stokes equations, hence one never knows the consequences except by comparison to a code that does. Better to continue using the CFD code. Knowing the errors arising from the assumption, it was possible to continue in conduction-only mode to speed up the process of sensitivity analysis;
- How CST solves the internal radiation transfer is unclear, and subject to doubt; and
- On the issue of importing CAD files: the author is not in favor of using brute force when trying to get insight in thermal problems. While modern tools make it easy to import CAD files, the not-so-easy next step is to get rid of all mechanical and electrical details that are useless for thermal modeling. While the speed of modern computers may allow millions of cells, the consequences are twofold: the layout becomes very complex, hindering insight in what is going on, and the CPU times go through the roof, hindering fast optimization.

Comparison with Experiments

A number of experiments were available for an existing prototype. While the author does not recommend to use general results for checking the accuracy of the numerical model, in this case, because the results are already available, a comparison gave some idea of trends, and could be used to extract some average boundary conditions in the lab. After calibration of the boundary conditions, the model and the experiments matched to within 2°C.

Under normal operating conditions the SOT solder temperature was above the recommended 100°C, the rest of the components appeared to be acceptable. The importance of radiation was tested, and found to be making a significant contribution to the cooling. Fixing a strip of gap pad material between the LEDs, bracket, housing and carrier had limited effect, however introducing a gap pad below between the bottom and main PCBs reduced the temperature by up to 6°C and hence is considered effective. The results, particularly the SOT temperature, was found to be sensitive to the assumed PCB thermal conductivity. Due to uncertainties in the model data, a gap pad was introduced.

As in many other cases encountered, we were faced with a specified maximum "ambient" for a module or component. This is impossible to design to, as the temperature within the system varies throughout the system so there is no one temperature a component sees as its own ambient. Another challenge is that the customer cannot control the design of the environment, in this case a car dashboard, into which this product fits, so defining the boundary conditions for Innolux's system is the responsibility of their customer, not Innolux.

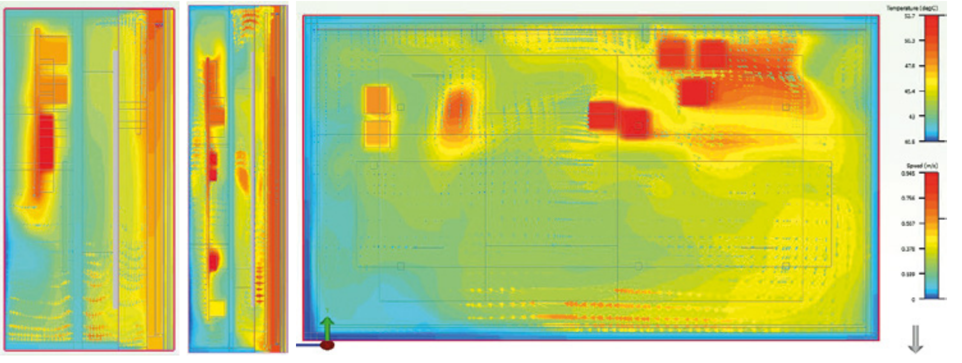

Figure 2. Typical results with flow, total dissipation 18.5W

It would be much better for the supplier to define a unique point at the outside of their component or module where a given temperature should not be exceeded. Such a spec is independent of the application and so avoids this issue.

Tests with a Dummy System

Tests with a dummy system should ideally focus on just a few issues, the most important being the real-life external boundary conditions for the complex display. Because of the complexity of the layout it does not make sense to model every detail, because it makes the fitting considerably more difficult. Unfortunately, this principle is often forgotten. Determining the boundary conditions that govern real-life applications is always a challenge, because to get sufficient accuracy one should simulate a very big part of the environment wherein the device is operational, including the radiators, the windows, the people etc. noted above. To avoid these problems, it is highly recommended to impose a heat transfer coefficient, including radiation, to be calibrated with real-life measurements.

Gap Pads

It is clear from the analyses that using gap pads or gap fillers improves the thermal performance. Be aware that the thermal data supplied by the manufacturers should be treated with caution, and gap pad data are not an exception unfortunately. The test method usually applies far too high pressure, resulting in too optimistic values. So, if critical, perform a dedicated test, ideally using Mentor Graphics' DynTIM system within which the pressure can be accurately controlled.

Recommendations

How to retrieve the right thermal data for all critical components, including the maximum junction temperature, how this is to be determined, and exactly now useful thermal data such as Rjc and Rjb are generated, requires investigation and discussion. It is highly recommended to ask the vendors of all critical components for more accurate models. For many components even basic but useful thermal resistances such as Rjb and/or Rjc are not available. As a customer, and especially if you build high-end or high reliability systems, you are entitled to get the right data, and especially when you will be held responsible for system failures!

Conclusions

The main conclusion is that, provided some measures are taken, the estimated temperature specs (as far as they are known), could be met, given the current dissipations and assumed boundary conditions. However, it could be foreseen that under certain circumstances these conditions would be worse, to such an extent that natural convection only cannot prevent overheating of the display at maximum ambient temperatures, and hence a forced convection solution should be explored. However, with the available numerical models of the system, it should be easy to check the consequences of such design changes.

In the opinion of the author, there is no other way to reach these conclusions within a realistic timeframe except by using a CFD-code combined with dedicated tests to confirm uncertain parameters required for the modeling. The biggest hurdle to improving the speed and accuracy of the design process is the lack of accurate data for the boundary conditions for the system, coupled with the widely-spread but incorrect habit of prescribing maximum ambient temperatures for the components.

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