DIGITAL INDUSTRIES SOFTWARE

Relying on Simcenter Flotherm

Enhancing the thermal design approach for automotive display integration

Executive summary

Innolux Corporation is a leading manufacturer of thin-film-transistor liquid-crystal display (TFT-LCD) displays and supplies customers that include many of the world's premier information and consumer electronics manufacturers. It has more than 68,000 employees worldwide and is a leader in the optoelectronics industry.

With the integration of a display-centered system into a high-end automobile, engineers at Innolux Technology Europe B.V. were confronted with solving expected thermal problems. This white paper covers the thermal design philosophy behind these activities.

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Introduction

A thermal model was already available based on CST Studio Suite, which had an embedded thermal solver with detailed mechanical computer-aided design (MCAD) data as input. However, there were some doubts concerning its accuracy for this application since the code can't be used to solve the Navier-Stokes equations. Furthermore, its radiation treatment was not well-documented and caused further concern. Hence, as a starting point for numerical analysis, the computational fluid dynamics (CFD) tool Simcenter™ Flotherm™ software, which is part of Xcelerator, the comprehensive and integrated portfolio of software and services from Siemens Digital Industries Software, was used.

The main objective was to provide preliminary models based on available (but not sufficiently accurate) input data to study the feasibility of the proposed complete system as a starting point for customer discussions regarding design decisions. 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. One key challenge was the system was being designed to operate in an environment where the ambient could be as high as 70 Celsius (°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, printed circuit board (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 for comparing 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 18.5 watts (W).

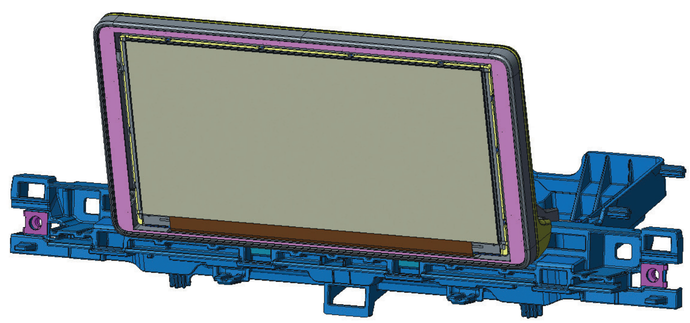

Figure 1: Center information display module.

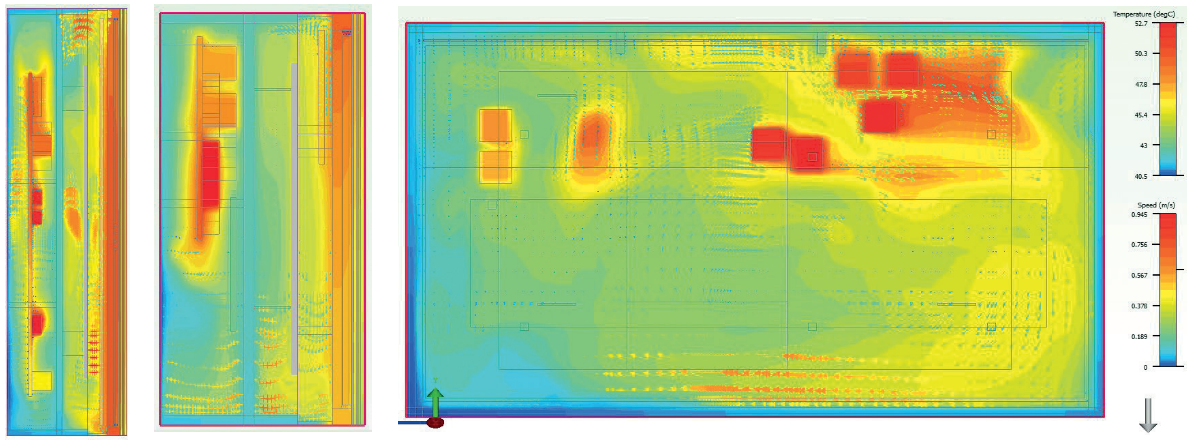

Figure 2: The typical results with flow is a total dissipation of 18.5W.

Results were made available to the customer for several system test conditions with 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.

The existing model was compared using CST Studio Suite and Simcenter Flotherm. After a series 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 proceeding with CST:

- The CST model does not solve Navier-Stokes equations hence one never knows the consequences except by comparing a code that solves the equation. 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
- On the issue of importing CAD files, I am not in favor of using brute force when trying to get insight into thermal problems. Although 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 complex, hindering insight into what is going on, and the central processing unit (CPU) times go through the roof, hindering rapid optimization

Comparison with experiments

A number of experiments were available for an existing prototype. Although I do not recommend using general results for checking the accuracy of the numerical model, in this case because the results were 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 experiments matched to within 2°C.

Under normal operating conditions the small outline transistor (SOT) solder temperature was above the recommended 100°C and 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 was 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, we were faced with a specified maximum ambient for a module or component. This is impossible to design as the temperature within the system varies throughout so there is no one ambient temperature for a component. Another challenge is the customer cannot control the design of the environment; in this case a car dashboard which this product fits in, so defining the boundary conditions for Innolux's system is the responsibility of their customer, not Innolux.

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 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 large part of the environment wherein the device is operational, including the radiators, windows, the people, etc., noted above. To avoid these problems, it is highly recommended you 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 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 much pressure, resulting in too optimistic values. So, if critical, perform a dedicated test, ideally using the Simcenter DYNTIM™ hardware in which the pressure can be accurately controlled.

Recommendations

It requires investigation and discussion to understand how to retrieve the right thermal data for all critical components, including the maximum junction temperature, and how this is to be determined, and exactly how useful thermal data such as junction-to-case resistance (Rjc) and junction-to-board resistance (Rjb) are generated. It is highly recommended that you 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, especially when you will be held responsible for system failures!

Conclusion

The main conclusion is that, provided some measures described above are taken, the estimated temperature specs (as far as they are known) could be met given the current dissipations and assumed boundary conditions. However, under certain circumstances these boundary conditions could be worse, to such an extent that natural convection 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.

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 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 practiced but incorrect habit of prescribing maximum ambient temperatures for the components.

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