Thermal Modeling for Application of High Power LED

White Paper

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Abstract

The Computational Fluid Dynamic (CFD) modeling of light emitting diode (LED) components becomes increasingly more important as CFD spreads into the design process. This paper compares the results of Avago's high power LED package (ASMT-MX00) on MCPCB and double layer FR4 substrate with heat sink, to experimental data. After the comparison discussion, a thermal modeling technique for LED package with heat sink is noted. Results are quite impressive, indicating that this technique can be used for LED system levels.

Nomenclature

R_{JA}	Junction to ambient thermal resistance (°C/W)
R_{JB}	Junction to solder point thermal resistance (°C/W)
R_{BA}	Solder point to ambient thermal resistance (°C/W)
T_J	Junction temperature (°C)
T_B	Solder point temperature (°C)
MCPCB	Metal core printed circuit board
CFD	Computational Fluid Dynamics

I. Introduction

The prediction of thermal performance of LEDs is becoming a necessity in reducing the time to bring products to market. However, with the increasing heat flux and package density, the heat dissipation of the LED package module is becoming a challenge, and the thermal analysis and design of the module is becoming even more important. CFD simulation is a widely used method for thermal analysis of electronic products in the early design stage. CFD is concerned with the numerical simulation of fluid flow, heat transfer and other related processes such as radiation.

This paper presents work done to create a high power LED package on MCPCB with heat sink and double layer FR4 with heat sink. First, a detailed model of an LED package-on-substrate is created, then a heat sink is created on the bottom of the LED package. Finally, this simulation data is compared to experimental data.

II. Thermal modeling Technique

The LED package, an MCPCB, double layer FR4 and heat sink were modeled using Flotherm, a CFD tool from Flomeric.

A. Model Description

Two models of heat sink have been developed: the detailed model and the compact model; The intent is to compare the error percentage between these two models. The detailed geometry parameters of the LED package and thermal conductivity of the package materials are shown in Table 1.

A schematic view of the front view and layout of the LED package is shown in Figure 1a and 1b. The solder paste is filled in, between the package and the substrate. When the package reaches the maximum power of 1.3W, the standard natural and forced convection cooling of air cannot maintain the junction temperature within the acceptable range. The additional heat sink works to help meet the requirements. In order to mount the heat sink onto the LED, an adhesion thermal tape is attached to the backside of the heat sink, and the heat sink is placed on the bottom of the LED substrate.

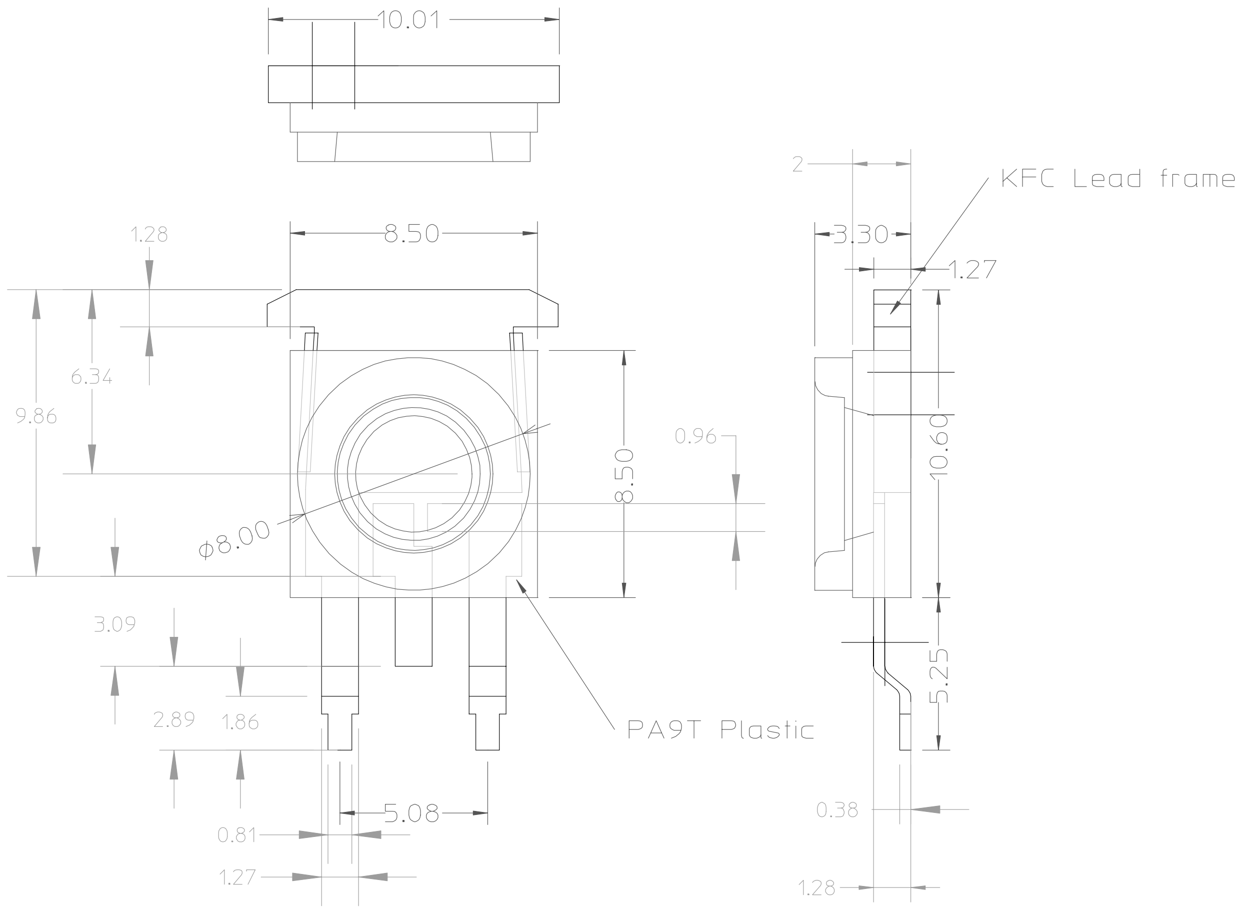

Figure 1a. Front and Side View of the Avago Power LED Package (ASMT-MX00)

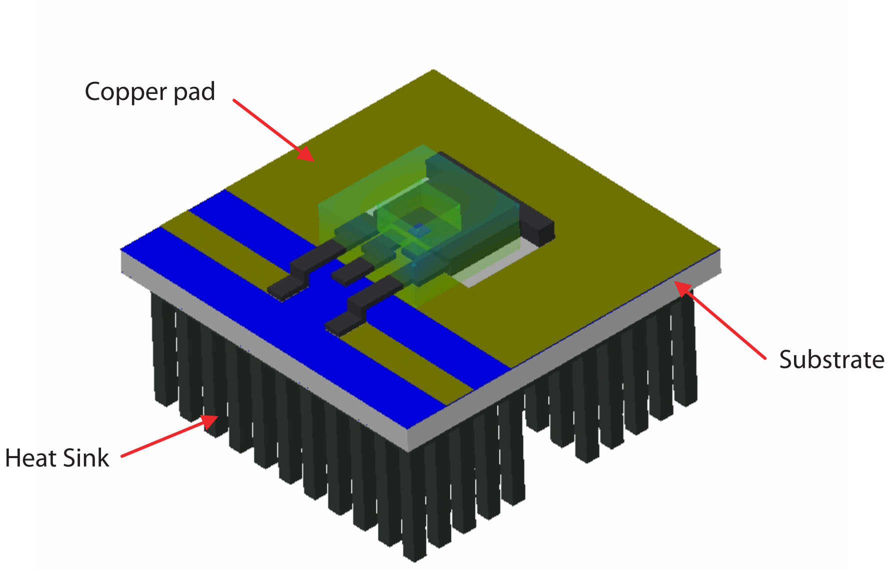

Figure 1b. LED Package on Substrate with Heat Sink

Table 1. Construction Details of the LED Package with Heat Sink and Thermal Conductivity of the Package Materials

No.	Component	Material	Thermal conductivity (W/m.K)	Dimension
1	Lead frame	Cu	364.25	Refer to above
2	Reflector	PA9T	0.2	8.5 mm x 8.5 mm x 3.3 mm
3	Chip	Sapphire	23.1	Junction about 0.11mm from bottom.
4	Encapsulant	Silicone	0.2	
5	PCB base	AluminumDouble Layer FR4	2000.3	37 mm x 26 mm1.6 mm in thickness
6	Metallization	Cu	385	35 µm in thickness
7	Dielectric layer	Alox	8	75 µm in thickness
8	Solder paste	SnPb37	50.9	25 µm in thickness
9	Thermal tape		2	Thickness of 0.125 mm
10	Heat sink	Aluminum	200	110 fins, base 23 mm x 23 mm x 1.5 mmFin height 8 mm, thickness 0.8 mm, Fin pitch size 1 mm

B. Grid and Boundary Conditions

For CFD analysis, the following properties are assumed:

- Three dimensional
- Steady state
- Airflow velocity of 0.2 m/s
- Air properties are constant
- Ambient temperature is 25°C
- Computational domain is 305 mm x 305 mm x 305 mm
- Heat is dissipated through natural convection and conduction
- Radiation effect is neglected because radiation affects are roughly 2 to 3 %

The total grid cells for the LED package-on-substrate with both the detailed heat sink model and the compact heat sink model are near 600,000 and 150,000 respectively. For the grid cells setup, there is a recommended use of at least 3 cells between the fins of heat sink (This is the default setting of Flotherm).

III. Results

A. Sample Package Configurations

The LED package is mounted on MCPCB and double layer FR4. It has dimensions of 32 mm x 27 mm x 1.6 mm. The heat sink is a typical finned-type with 110 fins and a base, made of extruded aluminum and is attached to the back of the MCPCB and double layer FR4 with thermal tape. The package is driven at 1.2W and the temperature of the solder point (TP) is measured at the heat slug of the package. Based on this data, the thermal resistance from the solder point to the ambient, RBA, can be calculated.

B. Numerical vs Experimental

Measurement data comparisons of the detailed model heat sink and the compact model heat sink are shown in Table 2. The visualization simulation results are shown in Figure 2a and 2b. As the approximation gets coarser, the agreement with real data becomes poorer. However, the percentage of error is acceptable for industrial applications. The fact that the simulated temperature is higher than the measured temperature indicates that the numerical model fails to account for some cooling phenomena. One source of cooling, which was ignored, was radiation. This difference could be due to measurement accuracy.

Table 2. Simulated Results vs Measured Results

	Measured RBA (°C/W)	Simulated RBA (°C/W)	Percentage Difference (%)
LED package on MCPCB with detailed model heat sink	25	23	8
LED package on MCPCB with compact model heat sink		27	8
LED package on FR4 with detailed model heat sink	37	35	8
LED package on FR4 with compact model heat sink		32	13.5

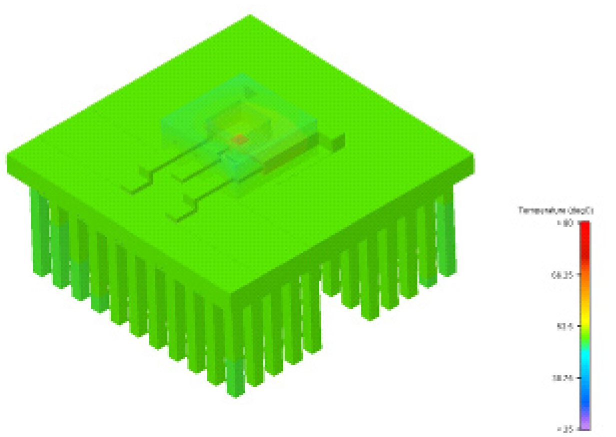

Figure 2a. Visualization Result of LED Package on MCPCB with Detailed Heat Sink Model

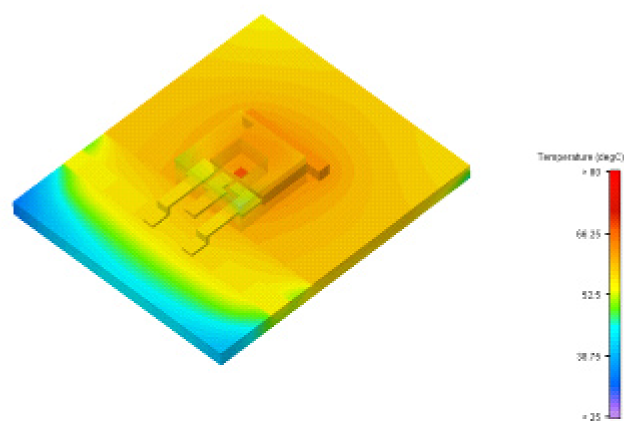

Figure 2b. Visualization Result of LED Package on FR4 with Compact Heat Sink Model

IV. Thermal Design Consideration

If the LED package has a design constraint to improve the package thermal performance, then the following approaches can help to reduce the temperature on the substrate and the junction temperature of the LED.

- Furnishing the backside with aluminum plates or heat sink
- Using separate PCBs for the driver circuitry and LEDs
- Using higher thermal conductive material for the dielectric layer
- Using fans to remove the heated air and to augment convection cooling

V. Conclusion

This study showed that the CFD modeling technique can be used for simulating the LED package-on-substrate with heat sink. The results clearly show that the detailed and compact heat sink models are providing good results to the actual measurement, however, the detailed heat sink model can be more time consuming. The compact heat sink model is good for doing fast analysis, the percentage of error is acceptable for industrial application, and it saves time The CFD is a good tool to assist in the design of the power LED into the real application.

Acknowledgment

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