LED Fundamentals

External Thermal Resistance – Substrates

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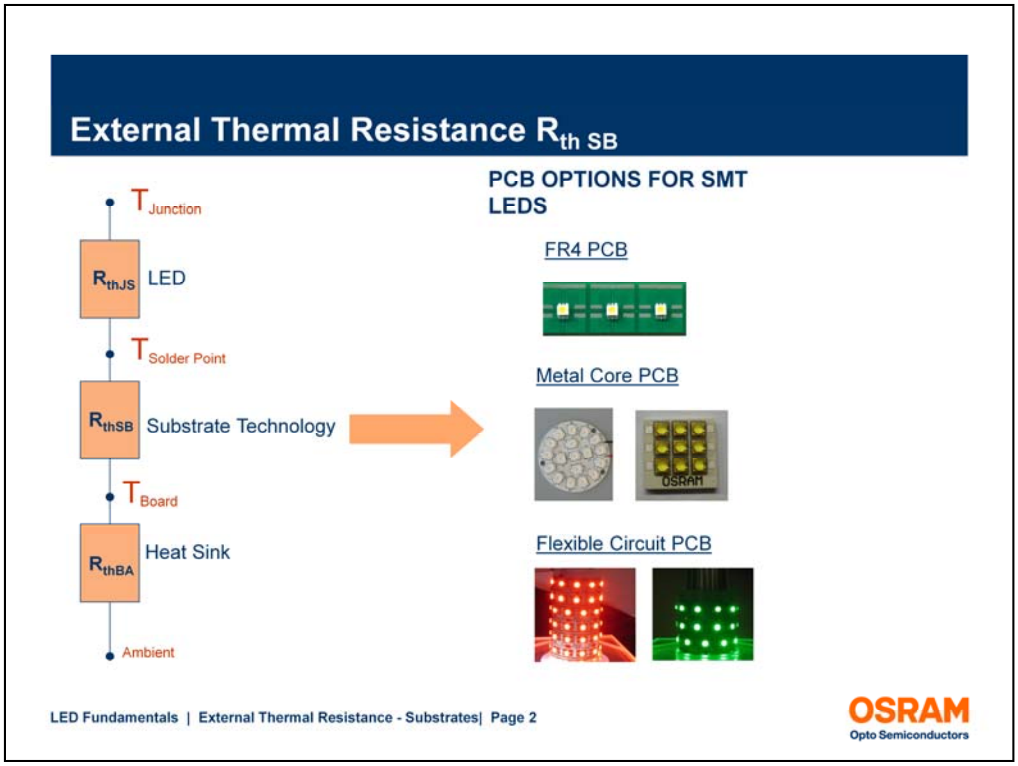
Hello and welcome to this presentation on “External Thermal Resistance – Substrates,” part of OSRAM Opto Semiconductors‘ LED Fundamentals series.

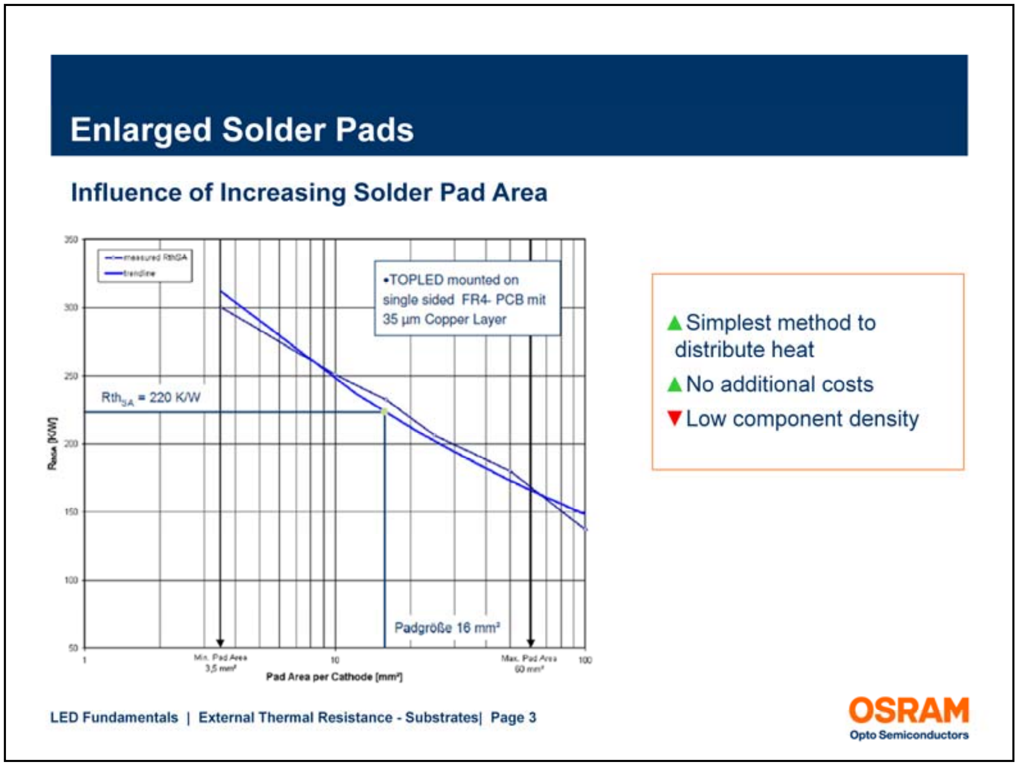
In this presentation we will look at the:

- Thermal resistance of various substrate types.
- Thermal management with printed circuit boards.
- Examples that compare the thermal resistance of various substrate technologies.

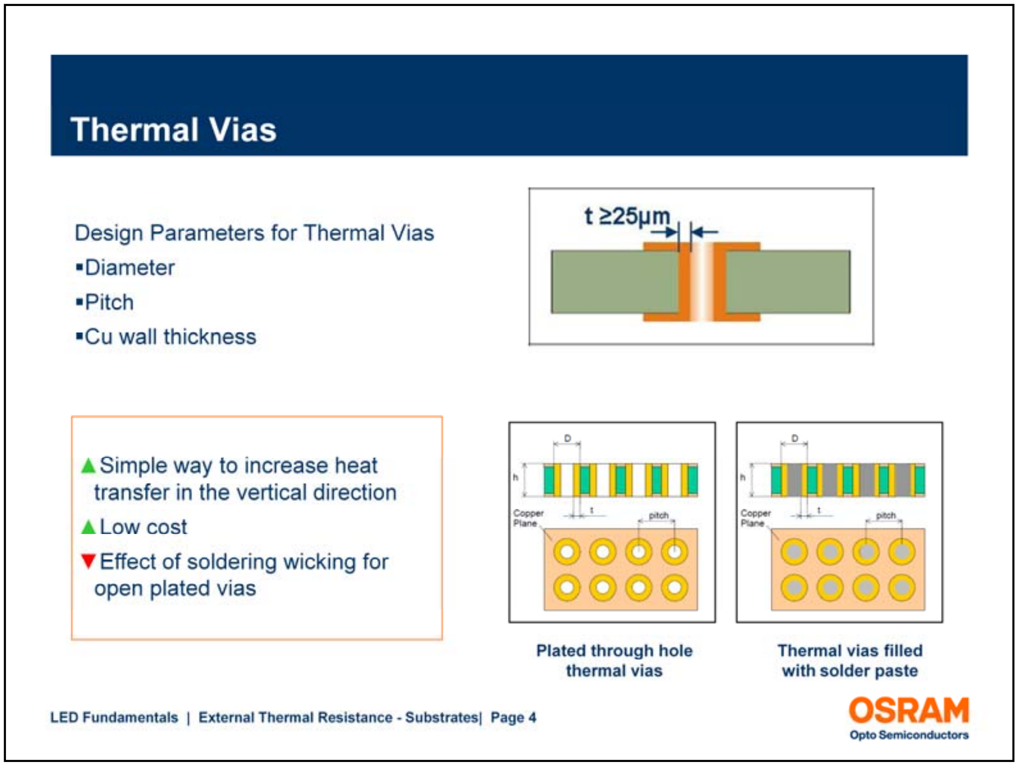


The LED Fundamental module, **Internal Thermal Resistance of LEDs**, discussed the internal thermal resistance of the LED package. In this module we will continue to discuss tracking the path of heat through an LED system and cover the thermal resistance offered by various substrates or printed circuit boards (PCBs) on which the LED component is mounted in a system.

Some of the more common types of PCBs used in an LED system design include FR4, metal core PCB and flex PCBs. In addition to serving as an electrical contact, PCBs also have to ensure efficient dissipation of the heat that is generated within the components, especially when working with high power components. The heat dissipation within a Printed Circuit Board is either in-plane (horizontal) or through plane (vertical) or a combination of both. There are various factors that influence the heat conduction in printed circuit boards and can be employed to reduce the thermal resistance of the PCB.



The value of the substrate thermal resistance can be lowered by enlarging the solder pad areas for the LED. The heat propagates through the enlarged solder pads and is spread in the in-plane direction of the PCB. Increasing the surface area of the solder pads is the simplest method to distribute heat on a PCB with no additional cost. However, it is only possible to implement in designs where there is a low density of components. The graph shows a decrease in thermal resistance of the substrate for an increasing solder pad area for a TOPLED LED mounted on an FR4 PCB.



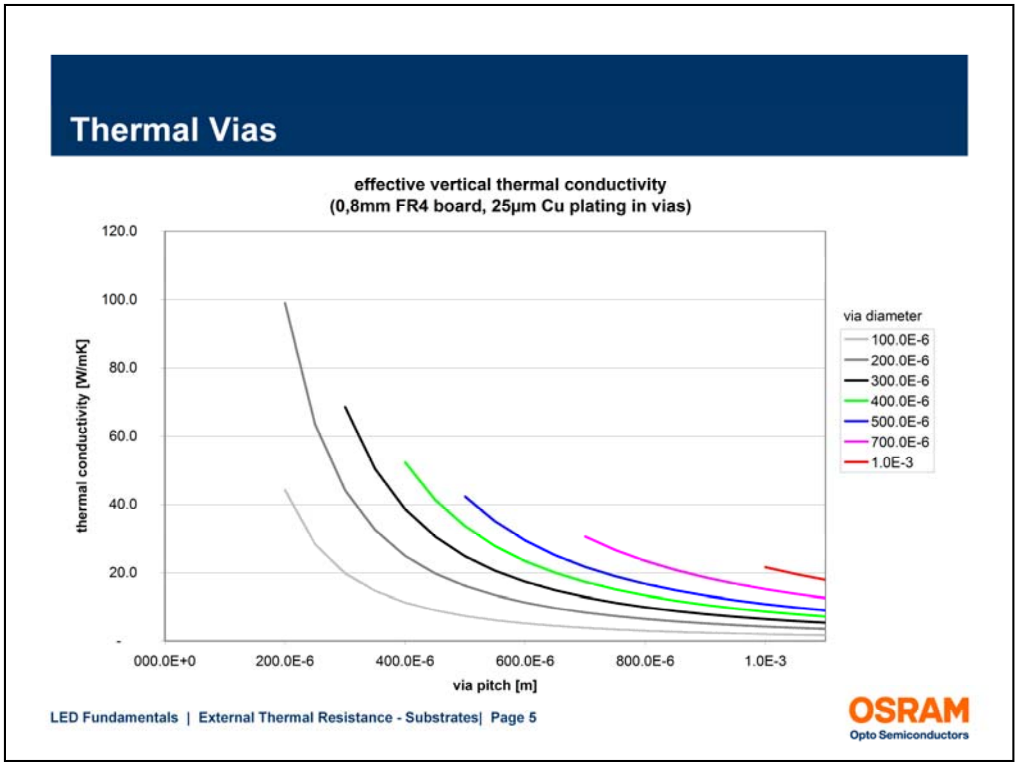
Thermal vias can be used to improve vertical or through plane heat conduction in PCBs. The thermal transfer capability of a network of vias is determined by various design factors such as:

diameter of the vias, pitch of the vias and thickness of the copper plating for the via walls.

Two types of thermal vias can be implemented: open plate through hole vias or vias filled with epoxy and then capped with copper. The filled, copper-capped vias offer an advantage as they can be arranged directly under the heat sink of the LEDs with no risk of solder run-off, which means heat can directly pass from the package on to the heat sink.

Thermal vias positioned close to the heat source dissipate the heat more efficiently and thereby reduces the thermal resistance of the substrate.

Finally, the thickness of the FR4 PCB also plays a role in the vertical conduction of heat. The thermal resistance of the PCB is directly proportional to the thickness of the material. This means the thicker the PCB material, the greater the thermal resistance.



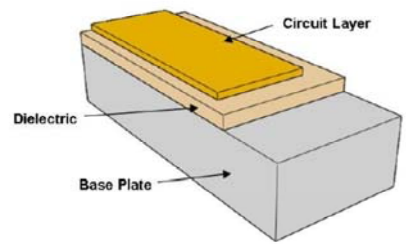
This graph depicts the thermal conductivity of vias of different diameters and pitch.

As the pitch between the vias and the diameter of the vias decrease, the thermal conductivity of the via network increases.

Metal Core Printed Circuit Board

Circuit Layer	Copper	~ 400W/mK
Dielectric	Polymer	0.9 W/mK – 3 W/mK
Base Plate	Aluminum or Copper	150 W/mK – 400 W/mK

▲ Good in plane and through plane conduction
▼ Costs higher than FR4
▼ Mostly single sided designs



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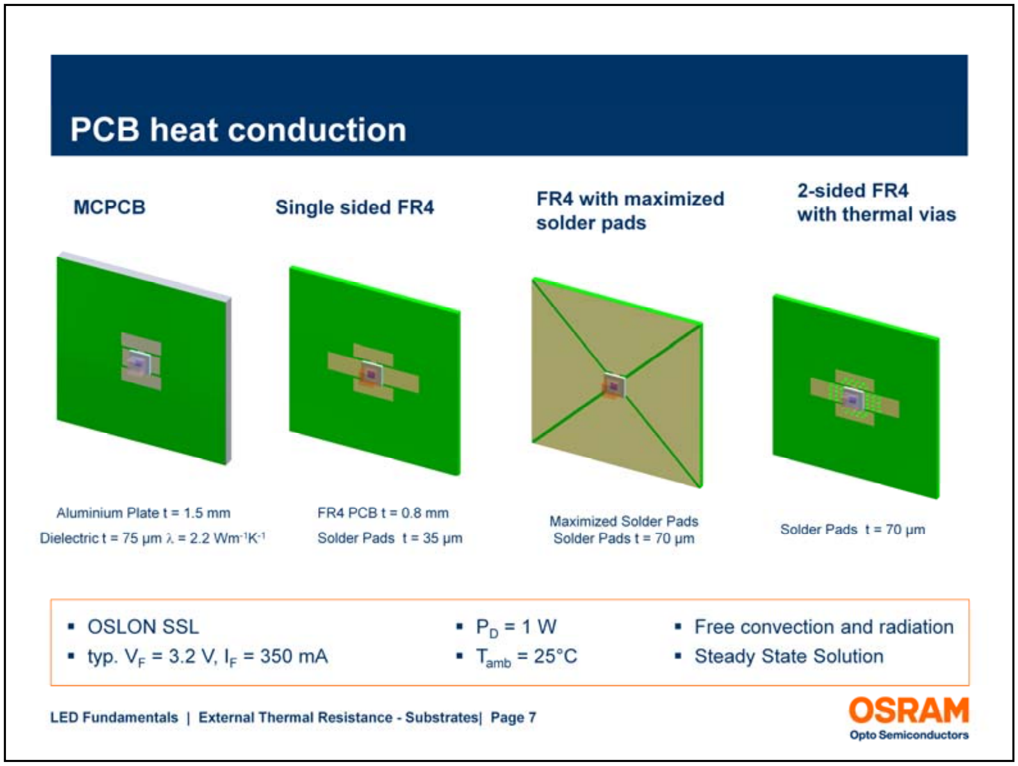
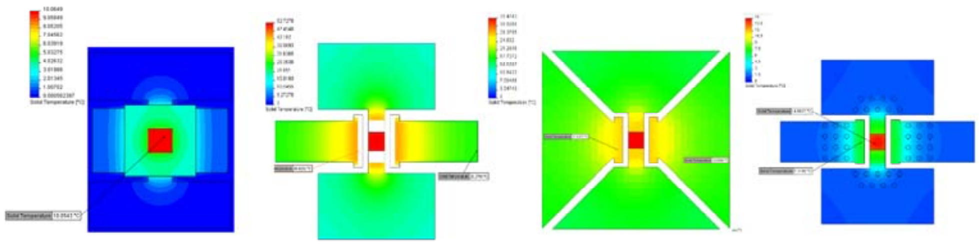
Metal core printed circuit boards usually consist of a base plate of copper or aluminum, a thin dielectric insulation layer, and a conducting layer of copper for the electrical connection. A metal core printed circuit board is ideally suited for both horizontal and vertical heat conduction. The downside is they are more expensive than FR4 PCBs and generally are limited to single side designs.



In order to show the thermal performance of various substrate technologies discussed in the previous slides, a method of numerical analysis is used. The goal of the analysis is a comparison of the thermal resistance of various substrate technologies under the same environmental conditions. Boundary conditions applied in all simulations are: 1 watt of heat, an ambient temperature of 25°C, a constant reference temperature on the backside of the board, and steady-state conditions under free convection and radiation. The thermal resistance of 7°K/W for the OSLON SSL was used for the thermal resistance from junction to solder point in all simulations.

PCB Heat Conduction



	MCPCB	Single sided FR4	FR4 with maximized solder pads	FR4 with thermal vias
Rth_{SB}	3K/W	45K/W	28K/W	8K/W
Junction Temperature Rise	10°C	53°C	35°C	15°C

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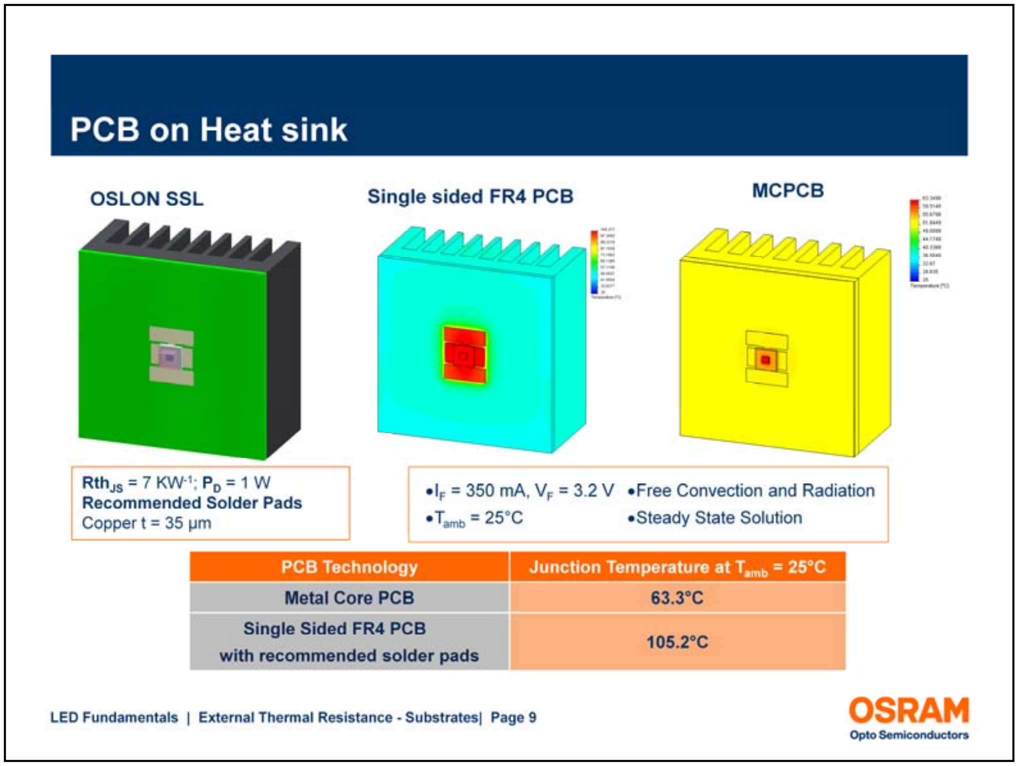
The figures on this slide show a section plot of the temperature distribution under steady state conditions. It also lists the thermal resistance of various substrates and the rise in junction temperature of the LED. The heat transfer is done by natural convection and radiation. The solder pad area, the thermal conductivity of the substrate material, and thermal vias play a significant role in these systems.



This slide shows the thermal performance of an FR4 PCB versus Metal Core PCB operating under the same environmental conditions on a heat sink.

In conclusion, optimizing the PCB Layout and choosing a substrate material with low thermal resistance is critical for heat dissipation in an LED system**.**

Please refer to the application notes “General Information on the Assembly and Solder Pad Design of the DRAGON Family” and “Details of the Assembly and Solder Pad Design of the OSLON and OSLON SSL Family” on the main OSRAM Opto Semiconductors’ website for additional information.

Thank you for viewing this presentation by OSRAM Opto Semiconductors.

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