Practical Heat Sink Design for Illumination

Introduction

LEDs are very small light sources that offer great freedom in design for lighting solutions. Within the freedom of an industrial product design, however, one has to make sure that the operating conditions of the LED stays within the ranges as defined in the datasheets on current and temperature, in order to ensure a good application lifetime.

Thermal Design in LED Systems

The LED (junction) temperature is a function of the ambient conditions, driving conditions and the overall thermal resistance to ambient conditions. Ambient conditions are usually a given. Drive conditions are usually defined by the amount of light that needs to come out of the lamp to meet product specifications. As a result, the technical design effort typically goes into creating a functional thermal solution that fits the desired (industrial) design.

To keep the temperature of the LED junction below the maximal rated temperature, the overall thermal resistance needs to be low enough. In Figure 1, a typical setup is shown:

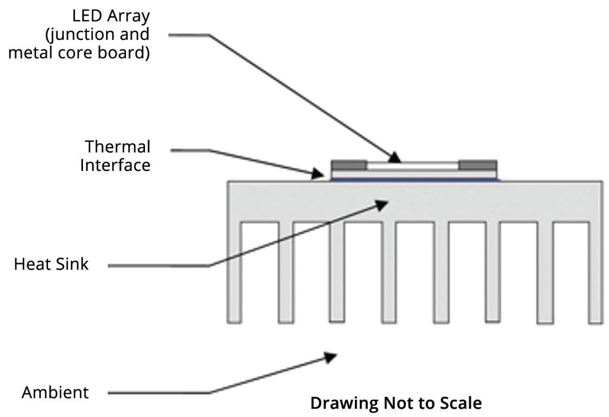

Figure 1. Typical setup of thermal resistance

The thermal resistance of the LED can typically be found in the datasheet but the thermal resistance of the PCB, thermal interface material and the heat sink need to be measured/calculated. As all thermal resistances are in series, all are important in order to reach a minimal junction temperature.

This paper focuses on what is important to optimize the heat sink performance.

Heat Sink Design Principles

A heat sink transfers the generated heat from the LED board to the ambient air. In order to get rid of the heat, the air should be able to flow freely or by force. The amount of heat that can be transferred by the heat sink to the ambient air is, amongst other things, a function of the air velocity near the heat sink, which is also called convection. Forced convection typically requires a fan or other mechanical solution. This is often not allowed for reasons of costs, noise and reliability. Therefore, most heat sink designs need to be optimized for so-called free (or natural) convection. This air flow is generated by heating the air that is passing the heat sink. As warm air is lighter than cold air, it will move up. This is called the buoyance effect. As the air will not move directly at the heat sink, a layer is formed around and in between the fins as shown in Figure 2.

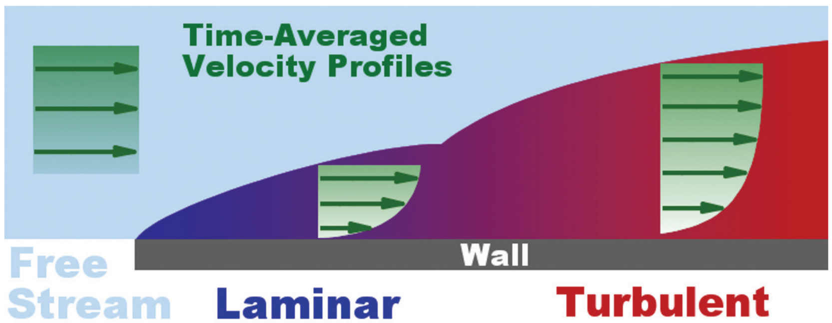

Figure 2. Heat sink design optimized for a free air stream

Practical Heat Sink Design for Natural Convection

In order not to stagnate or obstruct this flow, the spaces in between the fins need to be sufficiently large.

Figure 3 shows the thermal resistance of a heat sink of 100 mm x 100 mm with 45mm high fins is calculated for various fin spacing. Typically, the optimum option can be found at approximately 6-10 mm free space between the fins (see Figure 4). Anything below that distance and the natural convection air flow is obstructed. (Note: Heat sinks designed for forced convection, using a fan, are usually designed to function optimally with smaller fin spacing as the fan pressure enables air flow through smaller slits.)

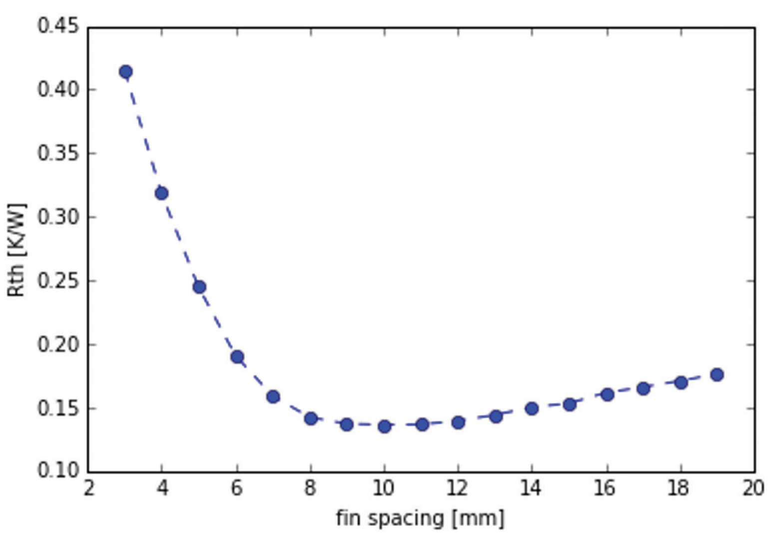

Figure 3. Heat sinks calculated with different fin spacings

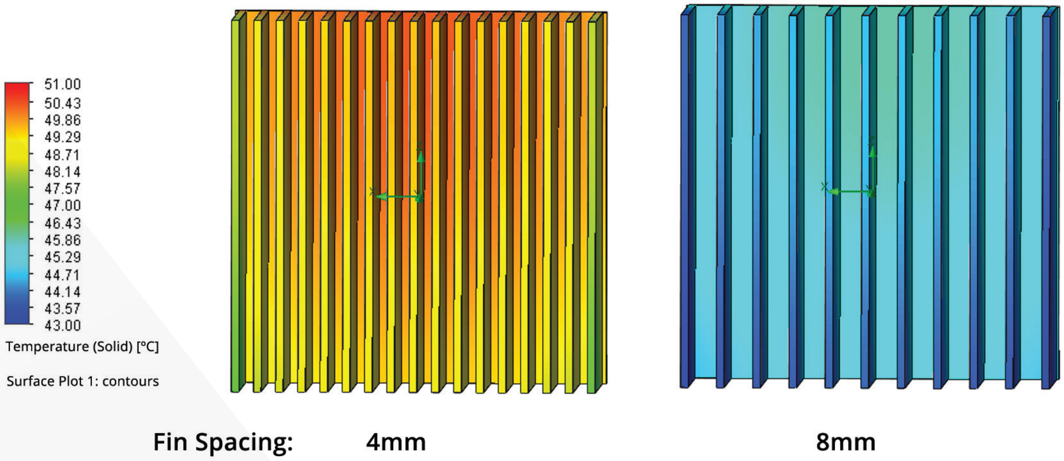

Figure 4. Optimum fin spacings of approximately 6-10mm free space

Conclusion

As a generic design rule, for a heat sink designed for natural convection, a space of approximately 8mm between the fins should be applied. This way, an optimal trade-off is made between the amount of fins (total surface area) and the allowed air flow.

About Lumileds

Companies developing automotive, mobile, IoT and illumination lighting applications need a partner who can collaborate with them to push the boundaries of light. With over 100 years of inventions and industry firsts, Lumileds is a global lighting solutions company that helps customers around the world deliver differentiated solutions to gain and maintain a competitive edge. As the inventor of Xenon technology, a pioneer in halogen lighting and the leader in high performance LEDs, Lumileds builds innovation, quality and reliability into its technology, products and every customer engagement. Together with its customers, Lumileds is making the world safer, better and more beautiful—with light.

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