

Thermal Design Considerations for Luxeon™ 5 Watt Power Light Sources

Luxeon 5 Watt Power Light Sources generate about four times the power dissipation of Luxeon 1 Watt Power Light Sources, making effective thermal design especially critical. In this Application Brief we discuss the thermal performance of two compact heat sink designs tested with the Luxeon 5 Watt Power Light Sources. These designs provide the Luxeon 5 Watt Power Light Source with a reasonable operating temperature range. This Application Brief extends the discussion started in AB05, *Thermal Design Using Luxeon Power Light Sources*, regarding thermal design considerations, heat sinks and specific procedures.

Luxeon Power Light Sources provide the highest light output with the smallest footprint of any Light Emitting Diodes (LEDs) in the world. With the introduction of the Luxeon 5 Watt Power Light Source, Luxeon significantly extends its strong lead in LED lumen output. A single 5 Watt white emitter package can output up to 120 lumens in the same footprint as a 30 lumen 1 Watt Luxeon Emitter. (Competing LEDs typically output only 2–3 lumens per emitter.) The small form factor and groundbreaking light output of the Luxeon 5 Watt Power Light Source provides lighting designers with even greater flexibility to explore unique product and design concepts. As with the Luxeon 1 Watt Power Light Sources, lighting designers need to become familiar with the impact of temperature rise on optical performance in LED devices. All Luxeon Emitter packages must be kept below the rated operating temperature through appropriate thermal design.

We recommend taking the time to develop a thermal model for your application before finalizing your design. The *Luxeon Custom Design Guide* provides important details about operating temperatures for each Luxeon emitter package.

Once you determine your target temperature, a thermal model will allow you to consider the impact of factors such as size and type of heat sink, and airflow requirements. Application Brief AB05 provides more information about developing a thermal model for your application.

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Minimum Heat Sink Requirements

As a rule, product applications using Luxeon Power Light Sources must be mounted to a heat sink for proper thermal management under all operating conditions. The Luxeon Star 5 Watt product consists of an LED mounted on a PCB and aluminum heat spreader (Al-heat-spreader). The Al-heat-spreader is designed to mount to a

heat sink, while the PCB provides the electrical connections. We do not recommend lighting a 5 Watt Luxeon Power Light Source for more than a few seconds at its rated current without first mounting to an appropriate heat sink. Use caution.

Thermal Modeling

A. Maximum Junction Temperature

The purpose of thermal modeling is to predict the junction temperature (T_{Junction}). The word “junction” refers to the p-n junction within the semiconductor die, where the light is generated and emitted.

The maximum junction temperature for a 5 Watt Luxeon Power Light Source is 135 °C.

The next section describes the components in a thermal model 5 Watt Luxeon Light Source.

B. Thermal Resistance Model

One of the primary mathematical tools used in thermal management design is thermal resistance ($R\Theta$). Thermal resistance is defined as the ratio of temperature difference

to the corresponding power dissipation. The overall $R\Theta_{\text{Junction-Ambient (J-A)}}$ of a Luxeon 5 Watt Power Light Source plus a heat sink is defined in Equation 1:

$$R\Theta_{\text{Junction-Ambient}} = \frac{\Delta T_{\text{Junction-Ambient}}}{P_d}$$

Where:

$$\Delta T_{\text{Junct. - amb.}} = T_{\text{Junction}} - T_{\text{Ambient}} (^{\circ}\text{C})$$

P_d = Power Dissipated (W)

$$P_d = \text{Forward Current (If)} * \text{Forward Voltage (Vf)}$$

Equation 1

Definition of Thermal Resistance.

A simplified model of the thermal path is a series-thermal resistance circuit, as shown in Figure 1A.

The overall thermal resistance ($R\Theta_{J-A}$) of an application using a 5 Watt Luxeon Star can be expressed as the sum of the individual

resistances of the thermal path from junction to ambient (Equation 2). The corresponding components of each resistance in the heat path are shown in Figure 1B. The physical components of each resistance lie between the respective temperature nodes.

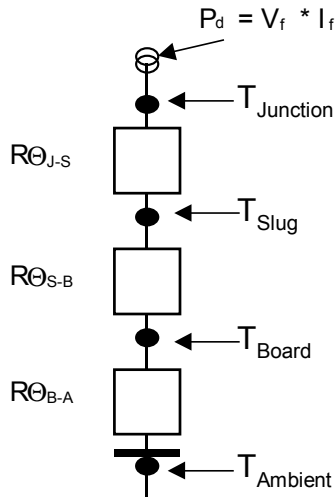


Figure 1A. Series Resistance Thermal Circuit

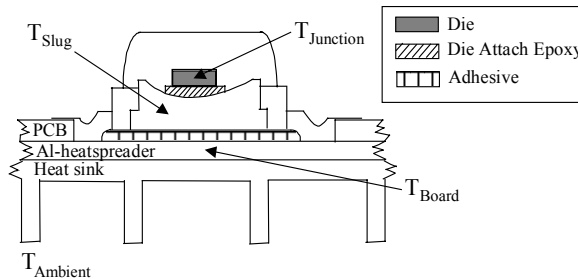


Figure 1B. Emitter Cut-Away

$$R\Theta_{Junction-Ambient} = R\Theta_{Junction-Slug} + R\Theta_{Slug-Board} + R\Theta_{Board-Ambient}$$

Where:

- $R\Theta_{Junction-Slug}$ = RΘ of the die, die attach epoxy and the slug.
- $R\Theta_{Slug-Board}$ = RΘ of the adhesive and the aluminum heat spreader.
- $R\Theta_{Board-Ambient}$ = RΘ of the adhesive between the heat sink and the aluminum heat spreader and the heat sink.

Figure 1A
Series Resistance
Thermal Circuit.

Figure 1B
Emitter Cut-Away.

Equation 2
Overall Thermal
Resistance.

C. Thermal Resistance of Luxeon 5 Watt Light Sources

In Luxeon Power Light Sources, Lumileds has optimized the junction-to-board thermal path to minimize the thermal resistance.

The thermal resistance of a Level 1 Luxeon Emitter (not mounted on a PCB with Al-heat-spreader) is represented by $R\theta_{\text{Junction-Slug}}$.

The thermal resistance of a Level 2 Luxeon Power Light Source (mounted on a PCB with Al-heat-spreader) is represented by :

$$R\theta_{\text{Junction to Board}} = R\theta_{\text{Junction - Slug}} + R\theta_{\text{Slug - Board}}$$

Typical values for $R\theta$ are shown in Table 1.

EMITTER DESCRIPTION	LUXEON EMITTER 5 WATT MOUNTED ON PCB WITH AL-HEAT-SPREADER LEVEL 2	LUXEON EMITTER 5 WATT EMITTER ONLY, LEVEL 1
	11 °C/W	8 °C/W
LAMBERTIAN (WHITE, GREEN, CYAN, BLUE, ROYAL BLUE)		

°C/W = UNIT FOR THERMAL RESISTANCE IN °Celsius/Watt

Note: Consult current data sheet for $R\theta_{\text{Junction - Slug}}$ and $R\theta_{\text{Junction to Board}}$

Table 1
Typical Luxeon 5 Watt
Light Source Thermal
Resistances.

Heat Sink Characterization

A. Test Set-Up

Two different types of commercially available aluminum heat sinks have been evaluated with 5 Watt Luxeon Light Sources. One heat sink has parallel fins (Figure 2A) and the second is a custom design with fins arranged in an "X" shape (Figure 2B).

Both heat sinks were mounted in an air tunnel with a fan. The fan was either turned **OFF**, to represent free (or natural) convection, or **ON**, to represent forced convection (Figures 3a and 3b). The heat sinks in the wind tunnel were oriented so that their fins were parallel to the airflow.

Secondary optics were not used in this experiment. Depending on the orientation, secondary optics can affect the convection flow

at the heat sink and thus the system thermal resistance.

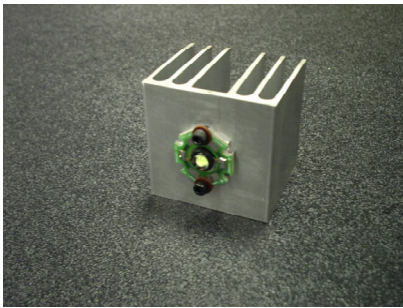


Figure 2A
Finned Heat Sink
Aavid Extrusion Part#
63065, LED mounting
face: 1.75" x 1.75".
Fin length 1.5".

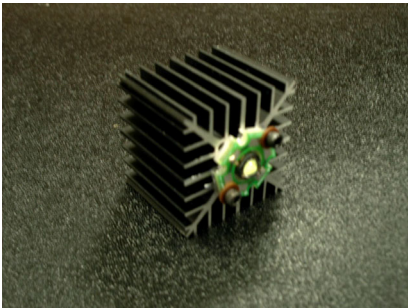


Figure 2B
X-Shaped Heat
Sink. LED mounting
face: 1.5" x 1.5".
Fin length 1.3".

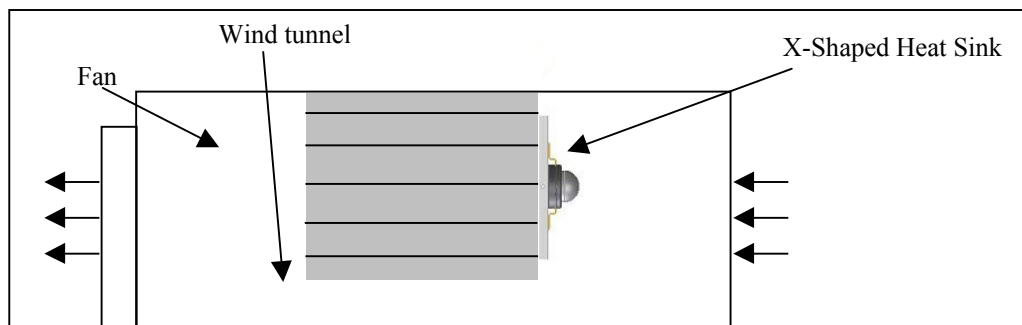


Figure 3A
X-Shaped Heat Sink
in Wind Tunnel.

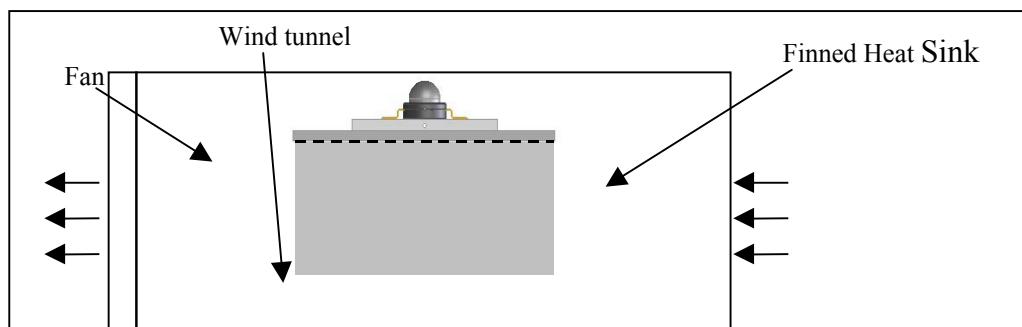
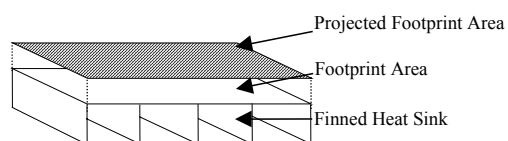


Figure 3B
Finned Heat Sink
in Wind Tunnel.

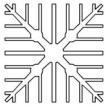
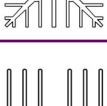
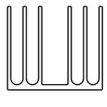
B. Definition of Heat Sink Size

The term “exposed surface area” is the total area of all surfaces of the heat sink exposed to convection. The “footprint area” quantifies the projected area of the heat sink as shown in the diagram to the right. The LEDs are mounted to the heat sink face that defines the footprint area.



An X-Shaped finned heat sink provides more exposed surface area in a given foot print when compared to a standard finned heat sink.

C. Heat Sink Comparison Table

TYPE OF HEAT SINK	CROSS SECTION OF HEAT SINK	FOOTPRINT AREA (INCH ²)	EXPOSED SURFACE AREA (INCH ²)	$R_{\text{THETA}}^{\text{J-B}}$ [°C/W]	$R_{\text{THETA}}^{\text{B-A}}$ [°C/W]	$R_{\text{THETA}}^{\text{J-A}}$ [°C/W]
X-SHAPED, FREE CONVECTION		2.25	34.5	11	8.5	19.5
X-SHAPED, WITH FAN		2.25	34.5	11	3.0	14.0
FINNED, FREE CONVECTION		3.10	36.2	11	9.0	20.0
FINNED, WITH FAN		3.10	36.2	11	4.0	15.0

Note: The airflow during the forced convection test inside the wind tunnel was 42 ft/min (0.21m/s).

Note: See the Luxeon Emitter and Star 5 Watt data sheets for the derating curves.

Table 2
Thermal Resistance
versus
Type of Heat Sink.

Additional Resources

The intent of this application brief is to provide the design engineer with a starting point for a good thermal design. The heat sink designs provide sufficient cooling for the 5 Watt Luxeon Power Light Source while maintaining a compact footprint. The data sheet derating curves should be used to adjust the drive current according to the thermal resistance Junction to Air.

These designs can be developed further through the use of thermal modeling and heat sink selection guides. In addition, many third party resources provide thermal design products and services to assist you with your design process.

Aavid Thermalloy offers extruded heat sink products. They also offer free software for selecting standard heat sink profiles and sizes based on a given $R\theta$. You can access that software tool and find links to other thermal analysis tools and software at the following web link: <http://www.aavidthermalloy.com/>

R-theta is another manufacturer of heat sink products. They also offer analysis tools on their web site: <http://www.r-theta.com/>

You can find additional thermal design resources and tools at these sites:
<http://www.electronics-cooling.com>
<http://www.coolingzone.com>
<http://www.thermalwizard.com>

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