Exclusive Case Study

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Flared Pin Fin Heat Sink Keeps LED Light Burning Brightly

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An LED lighting fixture manufacturer approached Cool Innovations in need of a natural convection cooling solution. In its latest lighting appliance design, this customer employed a 65-W LED lighting module cooled by a conventional extruded aluminum heat sink. Although the same heat sink had been used successfully in previous designs, it proved insufficient in this latest one. The LED module's high power dissipation caused the temperature at the LED board-to-heat sink interface to exceed the 70ºC temperature rating in ambient air specified for this design. Knowing that high operating temperatures diminish the LED luminosity as well as reducing the service life of the light, the customer was justifiably concerned.

The customer sent their heat sink to us to see if we could provide a better alternative. To this end, we conducted tests on the customer's existing heat sink and two heat sinks of comparable size from Cool Innovations. The customer's heat sink was a 2.5-in. tall aluminum extrusion, having a 5-in. by 5-in. base with 13 fins. The wide spacing of the fins indicated that this heat sink was optimized for natural convection. The two heat sinks from Cool Innovations featured the same foot print and height as the customer's heat sink but were built using pin fin construction. One of these heat sinks used vertically oriented pin fins, while the other heat sink was made with our flared pin technology. Photos of the three heat sinks under test are shown below in the table.

In these tests, each heat sink was mounted to a power resistor dissipating 65 W of power to emulate the customer's LED lighting module. A temperature probe was attached to the base of the heat sink, with placement of the probe as close as possible to the center of the base. This measurement represents the temperature that would be seen at the LED board-to-heat sink interface in the application. In each test, power was applied to the resistor, the temperature was allowed to stabilize, the heat sink temperature reading was recorded, and the thermal resistance of the heat sink was calculated. All measurements were taken at an ambient of 25ºC with no airflow, so heat sink cooling was due solely to natural convection.

Testing of the original extrusion under natural convection yielded a temperature of 79ºC on the heat sink base. From that temperature, we calculated a thermal resistance of 0.83ºC/W for the heat sink. Next, the vertical pin fin heat sink was tested. Its temperature measured 75ºC, which translates to a heat sink thermal resistance of 0.77ºC/W or 8% better than the extrusion. However, the 75ºC was not low enough to meet the customer's requirement for a 70ºC max temperature at the LED board-to-heat sink interface.

Finally the flared pin fin heat sink was tested. In this case, the heat sink temperature reached just 65ºC, which corresponds to a thermal performance of 0.62ºC/W for the sink. This represented a 25% reduction in heat sink thermal resistance when compared to the extrusion. More importantly, the 65ºC temperature met the customer's specification for maximum temperature at the LED board-to-heat sink interface. These results are summarized in the table.

The high performance of the two pin fin heat sinks is attributable to the omni-directional nature of the pin fins. In natural convection cooling where no forced convection is present, air flow is allowed to enter and exit all four sides and the top of the heat sink. The extrusion can only allow fresh air to enter from two sides, thus constricting the air flow. While both pin fin heat sinks outperform the extrusion, the flared pin fin heat sink performs better than the vertical pin fin heat sink because the flared pins provide greater spacing between the pin fins. With more spacing between the pin fins, air flow is enhanced, allowing the heat sink to 'breath' better.

Ultimately the customer opted to use the flared pin fin heat sink as it was the only one that met their requirements. Had they not found such a solution, they would've been forced to reduce the brightness of their LED light or undergo a significant redesign.

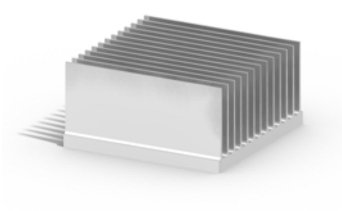
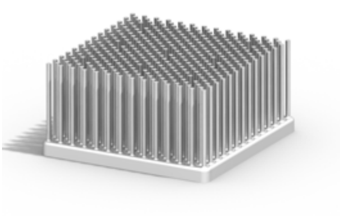
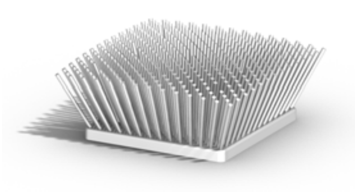
Heat sink under test	Heat sink dimensions and number of fins	Heat sink volume and surface area	Temperature measured on heat sink base	Thermal resistance of heat sink	Thermal resistance vs. extrusion
Extrusion 	5 in. (l) x 5 in. (w) x 2.5 in. (h) 13 fins	21.3 in^3, 332.2 in^2	79ºC	0.83ºC/W	Same
Vertical pin fin heat sink 	5 in. (l) x 5 in. (w) x 2.5 in. (h) 356 pins	18.7 in^3, 352.4 in^2	75ºC	0.77ºC/W	-8%
Flared pin fin heat sink 	5 in. (l) x 5 in. (w) x 2.5 in. (h) 356 pins	18.7 in^3, 352.4 in^2	65ºC	0.62ºC/W	-25%

Table. Performance of three heat sinks tested for use in a 65-W LED lighting application. Heat sinks were tested with a 65-W resistive load to emulate the customer's LED lighting module. The application required that the heat sink temperature not exceed 70ºC—a condition that was only met by the flared pin fin heat sink.

About the Author

Barry Dagan, P. E. is chief technology officer of Cool Innovations. Barry has more than 25 years of experience in thermal management design and holds multiple patents in this area.

For further reading on testing of natural convection cooling, see the How2Power Design Guide and search the Design Area category and select the Thermal Management subcategory.