

Application Note — Designing Around an Active Heatsink

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Background

In solid state lighting (SSL), LED heat dissipation increases as lumen output rises. For lower lumen packages, passive cooling can be used in most instances. For higher lumen modules, a passive heatsink may be considered too large and active cooling may be desirable.

This document describes design considerations specifically associated with active cooling. For general design considerations for passive cooling, see the Application Note “Heatsink Design” on the ‘Members Lounge’.

Forced Convection

Convection is the transfer of thermal energy from one place to another by bulk fluid movement. Forced convection is when the fluid flow is induced by an external source, such as a fan.

In typical SSL applications using forced convection, a fan or other air moving device is mounted on top of a heatsink that is attached to the LED module. The fan forces air to flow between the fin channels of the heatsink. Heat is transferred by conduction (heat transfer in solids) from the module to the heatsink and to the surrounding air by forced convection, thus cooling the module.

A fan/heatsink assembly such as this is called an “active heatsink”. Conversely, a heatsink that relies solely on buoyancy forces to create airflow (i.e., no fan or other air moving device) is called a “passive heatsink”. A representative active heatsink is shown in Figure 1.



Figure 1 – A typical active heatsink attached to a module

Design Considerations

Heatsink Size

The main advantage to active cooling is the ability to reduce heatsink size and weight while still achieving the same or better thermal performance when compared to a passive heatsink. If size and/or weight are an issue in a particular application, an active heatsink may be the best solution.

A comparison of heat sink size for a passive and active heatsink is shown below. XSA-48 is an active heatsink and is 70 mm in diameter, 60.25 mm tall, and 170 g (0.4 lb). XSA-54, the passive heatsink, is 120 mm in diameter, 70 mm tall from the back of the module and extends another 17 mm forward (87 mm total). XSA-54 is 575 g (1.27 lb).

XSA-48 is rated to cool a Thermal Class Q module in a 40°C ambient while XSA-54 is rated to a Thermal Class R.

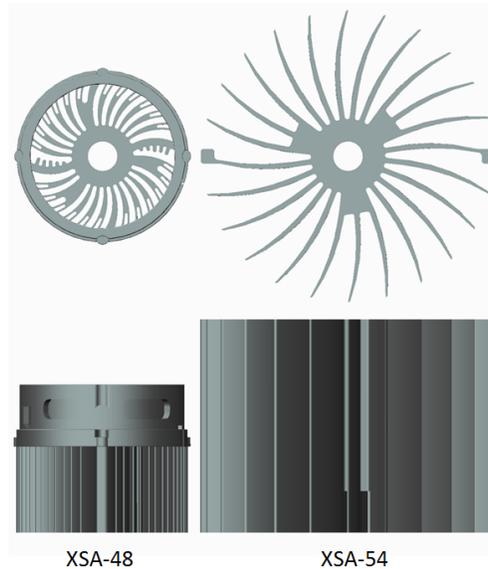


Figure 2 – Heatsink size: active vs. passive

While size and weight are factors that weigh in favor of active solutions, price is typically higher when compared to a passive solution.

Luminaire Orientation

Because active cooling is dominated by forced airflow, not airflow caused by buoyancy forces, orientation has little effect on the thermal performance of active heatsinks. Module case temperature, or T_c , is essentially the same in any orientation.

Active Heatsink Type

Several different types of active heatsinks currently exist on the market. Fan-based solutions and SynJet® coolers are the most popular. Common fan-based solutions include those manufactured by ebm-papst and Sunon. SynJet® coolers are manufactured by Nuventix. For specifics on each, contact the manufacturer directly, or your Xicato representative.

ebm-papst has developed fan based cooling solutions for Xicato products that are optimized for form factor, cooling capability, and lifetime/reliability. XLA-18 cools up to a Thermal Class U XLM while XSA-48 cools up to a Thermal Class Q XSM.

Operating Environment

Fans are typically rated to operate in a 40°C ambient environment. SynJet® coolers are rated up to a 60°C ambient. Operating above the rated ambient can cause reliability issues that are described later in this document.

Active Heatsink Power Supply

Typical active heatsinks are powered by either a 5 V or 12 V constant voltage source. Either a separate power supply or a driver with an auxiliary 5 V or 12 V output is required.

Fan Characteristics

Audible Noise

Noise is an important factor when choosing an active heatsink. Since many installations are in quiet environments, an active solution must have relatively low noise. Typical acoustics for active heatsinks used in SSL applications range between 7 dB(A) and 28 dB(A). For reference, the following table lists approximate decibel level for various noise sources.

Noise Source	dB(A) Level
Rock Concert	140
Garbage Disposal	80
Library	40
Whisper	20
Breathing	10

Table 1 – Decibel level for various noise sources

Acoustic noise is not strictly additive. For example, if a particular fan’s noise level is 20 dB(A), two of the same fan, running side-by-side, does not result in 40 dB(A) of noise. Adding noise sources is complicated, but the following equation can be used in order to determine an **approximation** for noise level for multiple active heatsinks in the same space.

Equation 1: $p_N = 10 \cdot \log_{10} i = 1N10p110$

Where:

p_1 is the sound pressure of one device [dB(A)]

p_N is the sound pressure of multiple devices [dB(A)]

For example, if a particular active heatsink has a sound pressure level of 20 dB(A), ten devices in the same room would have a sound pressure level of approximately 30 dB(A). The above equation assumes that all the devices are emitting sound from the same point in space. In reality, the devices are spread out from each other and the above equation does not take this into account. The equation, however, gives a general idea as to how loud a set of active heatsinks would be in a room.

The ebm-papst solutions mentioned earlier (XLA-18 and XSA-48) have been designed to run at lower RPM because of the patented thermal design of Xicato modules. The lower RPM results in a much lower noise level. The typical level for these solutions is 7 dB(A).

Lifetime

The lifetime of a passive cooling solution is essentially infinite. Since there are no moving parts, there is no mechanism of failure for passive heatsinks. This is one of the major attractions to passive cooling. As heat dissipation reaches the levels that begin to require active solutions, however, lifetime of the solution becomes a primary concern.

The lumen maintenance of Xicato products to L70/B50 criteria is 50,000 hours. In order for an active solution to be attractive, the lifetime must be at least as long as the life of the module.

Bearing wear is the typical degradation mechanism for fans. As the bearing wears, fan speed and air flow reduce, power consumption increases slightly, and operating noise level rises. In general, fan failure is not catastrophic until well past the L10 specification of the particular fan. The fan will still cool the module, though not as effectively as fan speed drops.

SynJet[®] degradation differs from fan degradation. The most common mechanism of degradation, according to Nuventix, is a rise in acoustics over time, even while air flow remains constant. Eventually, however, there will be a decrease in air flow, but significantly passed the rated lifetime of the module.

There are several metrics to use when comparing lifetime data of various active heatsinks. The most common are MTTF and L10. MTTF stands for “mean time to failure”. This is the average time it takes for an active heatsink to fail. This means that at the specified MTTF value, expect that 50% of the active heatsinks in the field will have failed. L10, however, signifies the time it takes for only 10% of the air-movers to fail.

Because of this, MTTF values are always higher than their corresponding L10 values, and an MTTF of 50,000 hours is not the same as an L10 of 50,000 hours. If the MTTF of one active heatsink is equal to the L10 of another, consider the one with the L10 value to have a higher lifetime. Because of this, Xicato recommends using the L10 value as an indicator of lifetime.

Furthermore, Xicato strongly recommends using an active heatsink that has an L10 value of at least 50,000 hours. This will ensure that at least 90% of the active heatsinks in the field will still be running at the rated RPM and noise level by the time the Xicato module reaches end-of-life. Also, remember that 10% of the active heatsinks that are no longer within specification will likely still be running adequately enough to cool the module, assuming enough thermal margin was built in to the design to absorb any reduction in fan speed after 50,000 hours.

Additionally, if an separate constant voltage driver is used to power the active heatsink, there is the added reliability risk associated with driver failure that needs to be considered.

Power Consumption

Power consumption of active heatsinks is negligible compared to the power consumption of the rest of the system. A typical active heatsink used in SSL applications consumes between 0.4 W and 0.6 W, whereas the rest of the system will consume around 50 W.

Luminaire Design

Venting

Adequate venting is required when designing around an active heatsink. For a fan to work properly, the pressure drop through the system must be low enough to provide adequate air flow. The same fan in different systems can induce very different amounts of air flow. To characterize this, fan companies provide fan curves, describing the amount of air flow the fan will produce when experiencing a given system pressure drop. An example fan curve is shown in Figure 3.

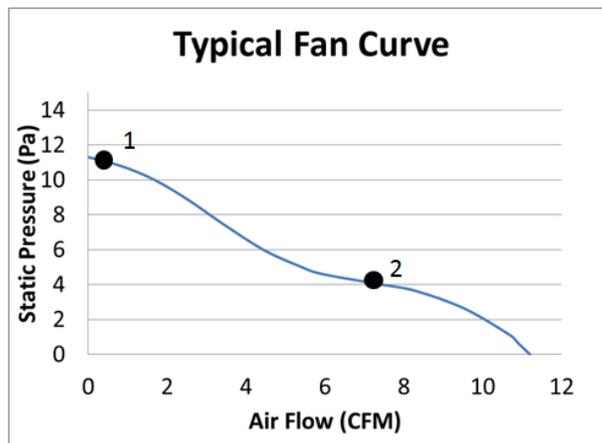


Figure 3 – Typical fan curve

Two points are shown in the fan curve. Point 1 represents a system where there is little venting, resulting in a very high pressure drop across the fan. As can be seen, the high pressure drop results in very little air flow, less than 1 CFM (cubic feet per minute).

The same fan in a different system that has a lower pressure drop can result in much higher flow: Point 2 on the fan curve, for example. Point 2 represents a system with much more venting, resulting in more air flow. Point 2 results in greater than 7 CFM. Again, this is the same fan in both examples; the only difference is the venting of the luminaire. Of course, the higher the flow through the fan, the lower the module T_c will be.

The points above are for example only, and the pressure drop through any particular system will be different.

Take, for example, a track spot luminaire. A poor design is shown in Figure 4. Although the rear of the housing is completely open, this design has absolutely no venting out the front of the housing. The pressure drop through the system is so high that very little, if any, air will flow through the fan and into the heatsink.

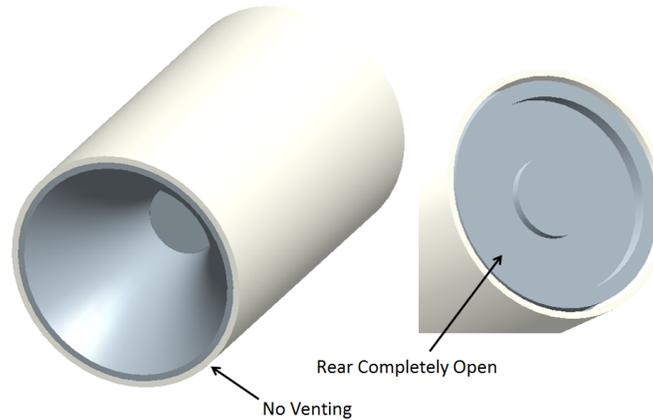


Figure 4 – Poor venting for track-based active cooling

A better design is presented in Figure 5. This luminaire was designed with venting in mind. The rear of the housing is grated so that enough air can enter the inlet of the fan. The front of the housing is also adequately vented. The diameter of the housing was designed to be large enough to allow for a small gap between the inner diameter of the housing and the reflector. Side vents were also added to the design to add an additional path for air to exit the luminaire. This design has a much lower pressure drop through the system and thus significantly higher airflow.

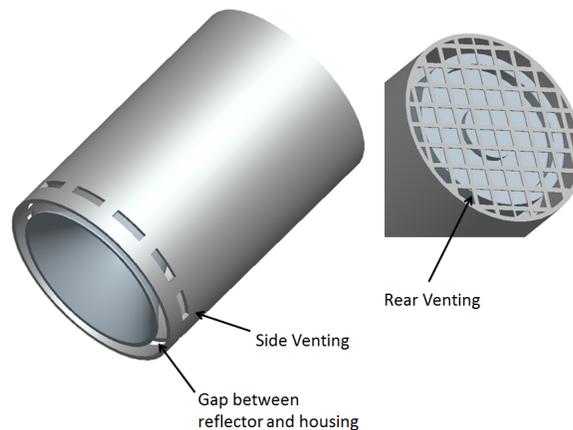


Figure 5 – Recommended venting for track-based active cooling

To see the difference between proper venting and inadequate venting, study the temperature plots in the following three figures. As can be seen venting plays a major role in active cooling.

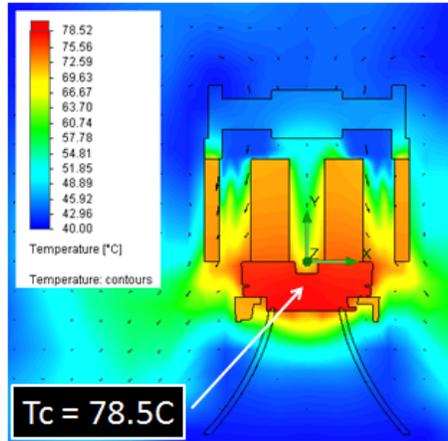


Figure 6 – Temperature gradient for no housing

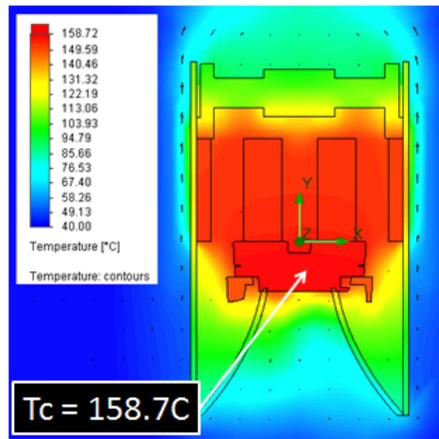


Figure 7 – Temperature gradient for housing with no front venting

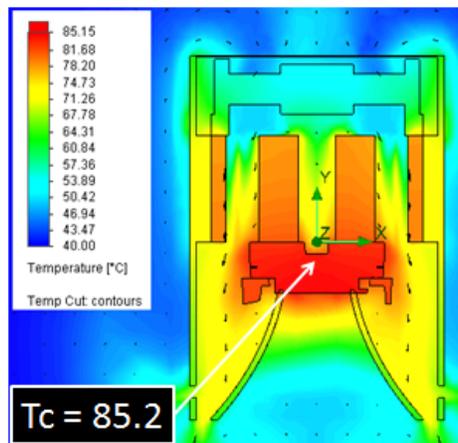


Figure 8 – Temperature gradient for housing with adequate venting

Active Heatsinks Inside an Enclosure

Active heatsinks are typically rated to operate at a maximum 40°C inlet ambient. Because of this, active heatsinks are usually not the best option for luminaires that are placed inside of an enclosure unless there is proper venting. The air temperature inside an unvented enclosure can get to 60°C or above, which would dramatically reduce the lifetime of the active heatsink.

The exception to this is SynJet®. Nuventix products are rated to a maximum 60°C ambient, and could be an appropriate choice when designing inside an enclosure.

For assistance regarding active solutions and enclosures, contact your Xicato representative.

Conclusions

Active heatsinks may be appropriate for certain applications where lumen output is high and size and weight of the luminaire are a concern. The above considerations should be taken into account when designing an active solution, including noise and lifetime of the active heatsink, luminaire venting, and heatsink cost.

Xicato can aid in the design of a luminaire that uses an active solution. Once an initial luminaire has been designed, Xicato can run a thermal simulation and determine pass/fail and provide feedback for design improvements. In order to submit a simulation request, download the Thermal Simulation Request and Definition Form from the 'Members Lounge' and submit to thermal.sim@xicato.com.