XICATO

LED Modules: Turning Up the Light, Taking Off the Heat

One characteristic typically associated with light-emitting diodes (LEDs) is that they provide "cool" lighting. While it's true that LEDs are cool to the touch because they don't generate much infrared (IR) energy, they do generate heat within the semiconductor structure, so the system must be designed in such a way that the heat is safely dissipated. The waste heat white LEDs generate in normal operation can damage both the LED and its phosphor coating (which converts the LED's native blue color to white) unless it's properly channeled away from the light source.

LED modules are increasingly utilized in retail, hospitality and other professional settings due to the benefits they offer, such as reliability, modularity, economical operation, and – more recently – color and quality of light. In a purpose-built LED luminaire, a fixture's thermal design is specified to support continuous operation without heat damage and oftentimes separates the LEDs from temperature-sensitive electronics, which provides an important advantage over individual LED replacement bulbs. When choosing a module for your lighting solution, there are some thermal-related considerations that are important to keep in mind.

Test Point Temperature

Test point temperature (Tc) is one characteristic that plays an important role during integration to determine the amount of heat sinking, or cooling, that the luminaire design requires. In general, the higher the Tc limit compared to worst-case ambient temperature (Ta), the more flexibility a luminaire manufacturer will have in designing or selecting a cooling solution.

The worst-case ambient temperature is usually 40°C or higher, so a module with a low Tc rating (e.g., 65°C) doesn't have much headroom above the already hot ambient temperature. Trying to keep a module at Tc 65°C when the Ta is 40°C and dissipating 40W thermal power is very difficult to do with a passive heat sink, so a fan or other active heat sink will likely be required. On the other hand, a module with a Tc rating of 90° C or higher (while still meeting lumen maintenance and warranty specifications) has at least 50° C headroom over the ambient temperature and should be able to make use of a reasonably sized passive heat sink.

However, the higher you can push the test point on the LED module, the smaller the heat sink you need. It's dependent on the Ta – if the module can't withstand a high enough maximum temperature, it's impossible to cool below Ta unless you have a refrigerated system, regardless of the size or effectiveness of the heat sink. Stretching the difference between Tc and Ta as much as possible will give you greater room to deviate from the norm and be creative in your heat sink selection. In Xicato's case, the intention is to continually push the temperature rating higher to provide more room to play and thus help push flexibility in customers' design capability, broadening their competitive advantage.

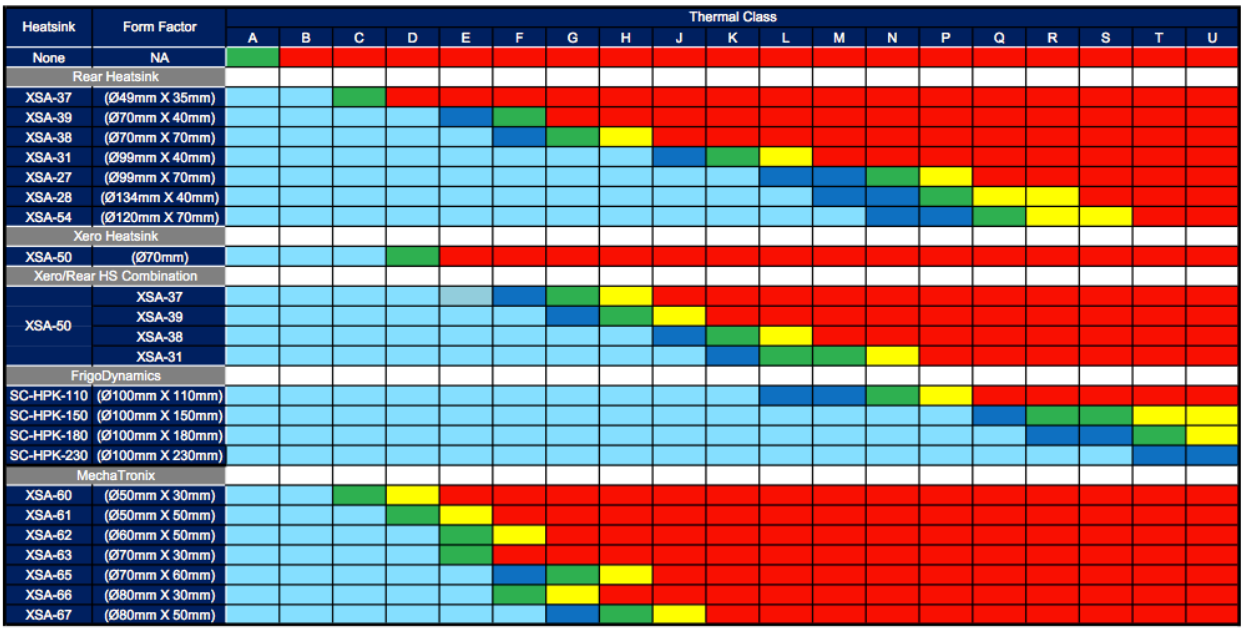
This highlights a key advantage associated with Xicato's proprietary Corrected Cold Phosphor Technology®: separating the phosphor from the LED, which allows phosphor temperatures to be

maintained at a stable level. Lack of stable phosphor/binder temperature is often the primary mechanism for degradation. Xicato is constantly improving this technology – what was launched five years ago differs from what is being built today – but the central principle of keeping the phosphor cold remains essential. There's a vital need to decrease the thermal resistance from phosphor to where the heat sink is located, and maintaining a clear path is difficult. To this end, Xicato is driving Corrected Cold Phosphor Technology® to create ever-lower resistance between the phosphor and the heat sink, without having to cool through the hot LEDs. Today, the module output is at 4000 lumens, which wouldn't have been possible five years ago. Evolving the technology was critical to enabling this capability.

The bottom-line considerations with respect to test point temperature are really flexibility and cost. If a module with a high Tc rating is chosen, there will be more options for design and cost savings than are provided by a module with a low Tc rating, assuming the same power dissipation.

Thermal Power

Another key characteristic, thermal power (load) has always been a difficult number to deal with. LED module manufacturers don't always provide the information required to calculate thermal power because this value can change based on such variables as lumen package, Color Rendering Index (CRI), correlated color temperature (CCT), etc. Cooling solutions are often rated for performance in terms of degrees Celsius per watt, which, unfortunately, necessitates calculating the thermal power.



Legend:

- LIGHT BLUE: Suitable for maximum ambient temperatures up to 50°C
- BLUE: Suitable for maximum ambient temperatures up to 45°C
- GREEN: Suitable for maximum ambient temperatures up to 40°C
- YELLOW: Suitable for maximum ambient temperatures up to 35°C
- RED: Not suitable for use

Figure 1. Xicato XSM module family sample passive heat sink matrix showing suitable module usage for a range of thermal classes.

To address this problem, Xicato has developed a "class system," through which each module variation is evaluated and assigned a "thermal class." With this system, determining the appropriate cooling solution is as simple as referencing the thermal class from the module's data sheet to a matrix of heat sinks. Figure 1 is a sample passive heat sink thermal class matrix for the Xicato XSM module family.

Let's take, as an example, a 1300-lumen module with a thermal class rating of "F." According to the matrix, for an ambient condition of 40°C, the best choice of heat sink would be one that is 70 mm in diameter and 40 mm tall. Validation testing is still required for each luminaire during the design phase, as variations in trims, optics, and mechanical structures can affect performance. Looking at the example module, if a manufacturer were to design a luminaire around this class "F" heat sink and nine months later a new, higher-flux class "F" module were released, the same luminaire would be able to support the higher-lumen module without the need for additional thermal testing. The thermal-class approach supports good design practice, speeds development and product portfolio expansion, and provides a future-proof approach to thermal design and integration.

Most specification sheets cite an electrical requirement for the module and the lumen output. Electrical input is basically the voltage the module will require and the current needed to drive it; the product of these two variables is power. The problem with output is that it's always displayed in lumens – a lumen is not a measure of power, but rather a unit that quantifies and draws optical response to the eye. It's calibrated specifically on what the human eye sees, but there's a quality of brightness that comes into play that can't easily be tied back to electrical power. There's no way to figure out exactly how much thermal power is being dissipated by the module – power "in" is measured in electrical energy (voltage × current), while power "out" is non-visible electromagnetic, visible electromagnetic, and thermal power. None of this is shown in datasheets.

This intangible factor creates a challenge – for most customers, a watt is a watt, but in reality, there are thermal watts, electrical watts and optical watts; not all are easily determined. The customer can attempt calculations – e.g., how to cool 10 thermal watts – but the fact is that people don't generally think that way. Many customers don't have engineers on staff, and those that do often use rough approximations to determine compatibility.

Removing the Guesswork

Xicato has addressed this challenge by taking the selection process a step further via its newly redesigned and updated website. Each module/drive current is assigned a letter to designate thermal class, so a user can simply go to the web page for the particular module (listed under the Products pull-down menu), select "Specifications," and easily see designated thermal classes for each drive current. Additionally, a user can select "Thermal Management" to view all available heat sinks and associated thermal class compatibility at different ambient temperatures. With this new capability, accessible without requiring a login or password, a luminaire maker can easily go in and identify how a

heat sink and module should be able to work together, without having to do any calculations. For customers that wish to design their own heat sinks, Xicato has application notes for guidance, as well as a free thermal simulation program that can accurately predict mobile temperature in desired ambient conditions.

Xicato has defined modules that go up to Class U. The Tc rating, while independent of module flux package, is interrelated. Class A modules, in general, don't need a heat sink; lower power modules usually achieve about 300 lumens. On the other hand, an XLM 95 CRI product is a Class U product that requires either a passive heat sink or an active heat sink. Higher-power devices would be employed where high illuminance is needed (e.g., retail), applications with high ceilings, or for outdoor architectural lighting (e.g., the front columns on the White House).

Once the module and heat sink have been selected and integrated into the luminaire, the next step is thermal validation, which Xicato performs for the specific fixture utilizing an intensive testing process that includes detailed requirements that must be met by the luminaire maker when submitting a fixture for validation (see Table 1 for a partial summary).

Table 1. Summary of Requirements for Luminaire Validation

- A production luminaire (components manufactured, processed and assembled to production specifications).
- Assembled with a module that represents the highest thermal class (worst case heat load) that will be used in the family. The thermal class rating for each module can be found on the representative product datasheet.
- Assembled with the worst-case thermal interface material (TIM) that will be used in production of the luminaire. Since Xicato modules come pre-assembled with a TIM, this only applies if the TIM is changed, or if a TIM is used in other areas of the luminaire.
- If the product family is adjustable or has an adjustable version, the adjustable luminaire that represents "worst case orientation" which generally means worst case flow conditions through the heat sink. Usually this is the luminaire with the greatest range of motion.
- Assembled with a driver that is typical for fixture family and represents highest wattage to be used.
- Assembled with an optic, reflector, glass, cover, media or other component that represents the most air restrictive or cooling inhibitive optical system. Often times this may be the stack up of several media (e.g. filter+ diffuser+ lens).
- Finished with paint, powder coating, anodize or other coating that creates the greatest thermal resistance and creates the highest temperature condition.
- Assembled with a trim or accessory attachment that represents the most air restrictive or cooling inhibitive trim or accessory.
- If a housing, chassis or enclosure is optional for the family, a representative enclosure must be included as part of the test. Examples include enclosures that are often required for satisfying UL safety requirements, or enclosures required to satisfy ceiling cutout requirements in accordance with IEC 60598-1 (or equivalent).

The validation is based not on lumens, but on the thermal class model, and the fixture rating is also based on thermal class, rather than wattage, because watts differ. With this approach, an upgrade can be made easily without having to do any retesting. This is another aspect of what makes LED modules like Xicato's future-proof, ensuring their ability to accommodate the lighting community's needs for many years to come.

Author: John Yriberri is the Director of Global Application Engineering at Xicato, Inc.

About Xicato

Xicato is passionate about light. Light has an emotional effect on people and a direct impact on business profitability. It ultimately influences everything in our lives. Xicato is a recognized leader in creating LED modules that provide superior aesthetics, economics and durability. Xicato aspires to be the trusted partner of the global lighting design community and luminaire manufacturers.