Thermal Management Challenges: The Ultimate Measure of LED Product Lifetime

- Heat is an unavoidable condition and concern with LED lamps
- Managing heat is crucial and one of the most critical factors in determining product lifetime
- Heat generated by LED's occurs within LED's themselves and it's vital for them to remain at or below optimal operating temperature
- Electronic components also emit heat and are most susceptible to heat damage
- Utilizing either active or passive cooling methods the heat generated from LED chips needs to be dispersed into the surrounding air
- Control methods such as *thermal foldback* reduce drive current to LED's if temperature reaches "maximum threshold"
- A vast array of thermal concepts are evolving that will greatly benefit LED efficacy

Full Discussion

Whether we're talking about the LED's and the light engine, or the power supply and driver electronics, heat is the unavoidable by-product that must be carefully managed and is often the ultimate determining factor in product lifetime. Though LED's are many times more efficient than a traditional bulb, they still turn as much energy into heat as they turn into light. How well this heat is managed is the driving factor in determining LED lifetime in the **LM-79** and **TM-21** reports, and must be taken into account at every step of the product design process.

Heat that is generated by LED's is not radiated into the air as it is with a conventional light bulb. In an LED, the heat is generated in the heart of the solid state device and must be removed from the LED's through a mechanical path that ultimately dissipates the heat into the air. This is done through heat sinks and creative cooling methods that fall into one of two categories; Active or Passive Cooling. Passive Cooling relies on large heat sink surface areas and natural air movement to remove the heat from the LED's, while Active Cooling uses an active element to facilitate the cooling such as a fan, liquid, thermoelectric element, or other. The LED's must be kept at an operating temperature at or below the temperatures stated in the TM-21 report for the projected lifetime numbers in the report to be valid.

Equally critical is controlling the heat that the electronics are exposed to in the fixture. The electronic components in the product are even more susceptible to damage and shortened lifetimes due to elevated temperatures. The power supply/LED driver electronics generate some amount of heat themselves (90% efficiency means 10% of the power used is being turned into heat by the power supply), and this heat in addition to the heat that is being generated by the LED's elsewhere in the fixture need to be kept away from the electronics.

Since the temperature of the electronics is potentially the deciding factor in product lifetime, it is often this temperature that is monitored to be kept in a safe working zone. "Thermal Foldback" is a term used to describe a control method where the product will decrease the drive current to the LED's if the temperature reaches a maximum threshold. Decreasing the drive current to the LED's also decreases the heat that is being generated by them, and a level can be found where the LED's are no longer generating a level of heat that will cause adverse effects on electronics' lifetime. In a good product design, this is only going to happen in situations where the temperature level is abnormally high; such as when outdoor lighting stays on during the heat of the day in a location such as Phoenix, Arizona. When temperatures return to normal, light levels increase to normal levels as well.

A common question regarding retrofit lamps is how they deal with the heat inside an enclosed fixture where there is no airflow. HID Lighting fixtures are intentionally made of material such as thin aluminum sheet or a very porous cast aluminum or "pot metal" that will not trap or retain heat generated by HID bulbs that can reach 450 to 765 degrees Celsius. This level of heat needs to be allowed to dissipate without the fixture glowing red hot.

The answer to how most retrofit and other LED products deal with inside fixture heat is that they use the fixture itself as an active part of the thermal path to dissipate heat to the ambient environment. By using active cooling, the heated air is circulated continually around the internal chamber of the fixture. In this way the heat is spread throughout the lamp compartment evenly, and the entire surface area of that compartment becomes a heat sink that will transfer heat to the cooler outside surface and subsequently into the surrounding air. Any movement of the ambient air surrounding the fixture will enhance this heat transfer.

When a retrofit (kit or screw-in) or integrated fixture (LED light engine and power supply/driver) use passive cooling typically a larger heatsink is used and substantially more and smaller LEDs are used. By using a larger array of smaller LEDs the heat is reduced and spread evenly over the heatsink area. The drawback with passive cooling is controlling over-temperature events or control failures where photo-eye or other type lighting dusk-to-dawn sensors fail and leave the LED light engine in continuous operating mode.

All LED lamps should be tested to an ambient temperature of 40 degrees C for normal operation, which is the highest recorded nighttime temperature on earth. At this temperature there is typically a temperature increase of 10 degrees C inside the fixture with the lamp at full power which should be within the operating range of LED products. In the event of an extreme temperature situation, such as during the day in desert locations where ambient temperatures increase beyond 40 degrees C and the lamps are still operating due to a sensor failure or human error, LED lamps that incorporate a thermal-foldback feature will gradually decrease their input current level to a point that they are not generating excessive heat that would compromise components. This is a critical feature so insure the LED lamps you are considering purchasing have this feature. Most LED failures in the market have resulted from over-heating or similar failure events as a result of an over-heated component. Over-heating can also lead to early LED chip failure, color-shifting or shorter than claimed life expectancy of the LED lamp or integrated fixture.

For more discussion of Active vs. Passive Cooling, see our whitepaper ***LED Fans - To Err or Not to Air***.

<u>Questions to Ask:</u>

1. What sort of cooling system is in place to effectively manage heat? Active or passive cooling?

2. From a thermal management perspective, does the product incorporate a thermal (foldback) function to protect LED chips and electronics from excessive heat impact?

3. What other steps have been taken to insure sustainable operation of the LED product in an enclosed fixture? What has been done to protect the LED semiconductors and LED driver/power supply components from excessive heat and environmental degradation?