Solid State Lighting: How Efficient is Your Design?

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Society is turning away from traditional incandescent lamps for lighting to reduce energy consumption, the related energy cost, maintenance costs, and power waste. Legislation requiring commercial building designs to reduce the power consumption is being presented in more states in the US and abroad. By reducing power consumption, we are also saving on power being used to removing the heat generated by the lighting systems i.e. air conditioning. Incandescent lamps are often referred to as heaters. Commercial and residential consumers are taking advantage of the long term maintenance related savings of the newer, longer life lighting systems. The long term power savings will reduce the number of power plants we will need in the future.

The most common technology replacing incandescent lamps is compact fluorescent (CF) lamps. Today's lower cost of CF lamps makes the payback quicker than ever. There are still some issues related to CF lamps such as color rendering, low temperature start up, and the use of Mercury.

Light emitting diodes are now entering the market as the replacement for both incandescent and CF lamps. The increase in LED efficacy, optics and power converter efficiencies are making solid state lighting designs more tempting than ever. "While the LED operating life is longer than CF and incandescent lamps, the up front cost of LED based lighting is still an issue." As more LED lighting designs are developed for commercial and residential usage, the costs will become more attractive.

When designing an LED based lighting solution the most important performance to be addressed is the system efficacy (lumens per watt). It is affected by every component in the assembly. It is very important how the total system efficacy is measured. The amount of light that falls within the target area for the amount of power supplied to the installed system after thermal equilibrium is attained should be the standard measurement of the system efficacy.

Be wary of how the LED efficacy is being presented. LED manufacturers will test the intensity with the junction temperature at 25°C and a specific forward current and ignore the intensity versus junction temperature curves and the drive current versus intensity curves. The steady state junction temperature and application drive current need to be part of the efficacy measurement.

The optical efficiency of the lighting system will have an impact on the system efficacy. LED systems are designed to project the light in a specific direction and to illuminate a target area. All light that falls outside the area is wasted and should be minimized. The optical design needs to transfer as much available lumens to the target as possible. Modeling software can be very helpful in optimizing the optical performance of the system.

Thermal management will be the next hurdle for the lighting system. Junction temperature is the enemy of the LED efficacy, color stability, and reliability. The thermal performance of the component, substrate, and housing needs to be considered for maximizing the system efficacy. The thermal path resistance of a light engine installed in a housing which does not allow proper convection will reduce the overall thermal performance. Thermal modeling of the system will help adjust the mechanical components to improve the cooling of the light engine. As light engines increase in power density, the need for thermal management becomes very important.

Power conversion in the LED drive circuit will influence the system efficacy and if it is contained inside the housing it will also impact the thermal performance. The less efficient the converter circuit is the more power it will dissipate. Linear current regulators can add 10°C to the LED junction temperature when they are on the same substrate. Place the converter outside the light engine housing if possible. Don't let a more expensive switching current source sway you away from its efficiency benefit. The power savings over time will offset the up front cost. As limitations are placed on the amount of power allowed for commercial buildings, the efficiency of the converters become more important.

We must also consider the cost of performance optimization. No one will be interested in a highly efficient system if the cost is out of line. The designer will improve the system and then reverse the changes to bring the cost to within the program target. Deciding which changes to reduce the cost with minimal impact to performance is the key to maintaining the balance between performance and cost.

Every component has some impact on the system efficacy. It begins with the LED selected and is proportional to the efficiency of the secondary lens. Lower thermal resistances of the component package, substrate, or housing reduces the junction temperatures and increases the system performance. A higher power conversion efficiency of the drive circuit reduces the amount of wasted power. The optimization of these components will result in a lighting system with lower power consumption and higher long term savings.

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