LED Standards Watch: ENERGY STAR Solid State Lighting Luminaries

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As the use of LEDs within the lighting market continues to grow, the importance of industry standards and guidelines are critical to enabling broader adoption and acceptance within both the commercial and residential markets. One of the standards currently in development is the US ENERGY STAR Solid State Lighting (SSL) Luminaries effort. While ENERGY STAR programs are voluntary, their impact can be far reaching. For example, one of the early ENERGY STAR programs that benefited LED technology focused on high efficiency traffic signals and mandated a maximum power limit depending on the type of traffic signal. The only lighting technology that could meet these requirements was LEDs. This standard was recently suspended because the US Congress has mandated minimum standards displacing the need for voluntary standards. A similar activity is occurring at the regional level where the California Energy Commission (CEC) has set minimum efficiency standards on external power supplies used for products such as laptops, printers and cell phones chargers that are based, in part on ENERGY STAR guidelines. The decision by the CEC has far reaching impact since most manufacturers will want to ship the same product throughout the country. One of the main objectives of ENERGY STAR guidelines is to aid consumers and businesses in making energy smart choices but as these examples illustrate, initially voluntary guidelines have become codified into regulatory requirements.

Since lighting is ubiquitous in society and LEDs are a relatively new technology within the general lighting area, it is important that LED-based products placed in the market meet certain norms that consumers would expect such as minimum light output and color. The approach that the Department of Energy (DOE) is taking in setting these standards is based on the recognition that LED technology is evolving rapidly as illustrated by the frequent announcements by LED manufacturers of new efficacy breakthroughs being achieved on a regular basis. Nevertheless the energy savings claims are not necessarily being realized in available products on the market. The first focal point is on a set of near term lighting applications, defined as Category A, where the existing LED efficacy is sufficient for market adoption such as portable desk task lights, outdoor path lighting, recessed down lights and under-cabinet lighting.

The requirements focus on four key attributes including minimum light output, luminaire efficacy, correlated color temperature (CCT) and zonal lumen density. What is quickly apparent in these attributes is that the EPA has taken a very different approach than it has with other lighting specifications such as CFL lamps and residential light fixtures. In those specifications, the figure of merit is lamp efficacy (lamp lumens/input power). In this case, because the standard is applications based, the metric is luminaire efficacy that is based on the complete system and covers the delivery of light to a specific area (zonal lumen density). Optimizing luminaire efficacy illustrates some the challenges of designing with LEDs. First, LED light output is a function of the operating temperature of the LEDs, so while LED manufactures specify minimum luminous flux at a junction temperature of 25°C, the actual output is dependent on the operating conditions. So the effectiveness of the thermal management approach is captured within this specification. In addition, there is no target LED driver efficiency in this guideline that is captured included in the overall calculation of efficacy. There are also standards for minimum light output, which is critical as many LED products on the market tout energy efficiency but do not provide sufficient light output compared to the existing products that they are intended to replace such as fluorescent lights.

As an example, the portable desk light standard must achieve a minimum of 200 lumens with a minimum luminaire efficacy of 29 lm/W and 85 percent of the total light output must be delivered within a zone of 0 to 60 percent (zonal lumen density). This gives the designer significant flexibility to trade off LED type (low, medium, high current), optical design, driver selection and efficiency, as well as thermal management. For example, using a few high power LEDs (>350 mA) requires improved thermal management since the heat generated is concentrated within a smaller area versus an array of medium power (100 to 150 mA) LEDs. Yet the optical design for the few LED case may be less complex since it simply requires that >85 percent of the light output to fall within a 60 percent zone, so it may prove easier from an optics perspective. The final remaining key requirement is the CCT and the specification is attempting to drive consistence to the already established norms for fluorescent lamps. For the desk light examples, there are six allowable CCTs ranging from 2,700°K to 5,000°K, which maps into the commonly considered warm to neutral white light range that a consumer would see on the shelf.

The proposed specification encompasses numerous requirements including a minimum three year warranty and a minimum color-rendering index (CRI) for indoor luminaries of 75. There is also a lumen maintenance requirement, which states that after 35,000 hours, the light output must be a minimum of 70 percent of the initial value. Some of the far requirements in the standard apply to power architecture and driver requirements. ENERGY STAR requirements are primarily oriented at saving power and setting thresholds sufficiently high that only a fraction of the products on the market meet the energy standards. For this standard, since there is a limited set of products on the market today, the targets were based on comparisons to existing fluorescent products. In addition, the DOE has been performing commercial product testing of existing LED luminaries to establish baseline market performance. One of the observations of this effort is that numerous products consumed power when they were off, in some cases more than 2 W.

This had the net effect of lower the efficacy of the system since most lights are only used a fraction of the day but this standby power is consumed around the clock. With one exception, the standard requires that there be no off-state power drawn. This effectively eliminates the use traditional off-the-shelf plug in wall adapters even those optimized for LED constant current drive since when the fixture is off there will be some standby power consumption in the wall adapter. For cost sensitive residential applications, this might have been a viable design option since it would allow the manufacturer to create a single plug in LED driver that could be used for numerous luminaries thus simplifying and reducing the development cost. Now the power supply must be embedded within the product with a switch between the AC plug and the driver, thus assuring no off state consumption.

The other specification that most developers might not have been concerned about in the past is power factor (PF). This is the ratio of the real power (P) to apparent power (S) and can vary from 0 to 1. If the load is purely resistive such as an incandescent lamp, input current and voltage is in phase and the PF is 1. The concern about power factors lower than 1 is that it requires the power utility to generate more than the minimum volt-amperes necessary to supply the real power (watts). The DOE is proposing a minimum PF of 0.7 for residential applications and 0.9 for commercial applications. Unfortunately the inductive and capacitive elements of a switch mode LED power supply do not appear as a resistive load and this type of circuit can have a power factor of 0.5 to 0.6 so additional circuitry, either passive or active is required in the design to meet this requirement. While "good" power factor is a real issue, the proposed requirement is more stringent than the existing ENERGY STAR standard for Compact Fluorescent Lamps (CFL) is 0.5.

The SSL Luminaries requirements are currently in development and Version 1.0 (March 9, 2007) is still in the review stage but the target the DOE is driving toward is to have the specification finalized and put into effect in March 2008. While this specification has been in development for some time, the timing is gated on other standards and test procedures being in place. The DOE and industry efforts should assure that products that meet these requirements will showcase best-of-breed products.

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