From: Scott Riesebosch [mailto:scott@crselectronics.com]
Sent: Monday, February 16, 2009 9:35 PM
To: richard.karney@ee.doe.gov; SSL
Subject: Energy Star standard for replacement lamps - comments from CRS Electronics

Richard and DOE SSL Team,

First of all, I want to thank you for all your hard work on the Energy Star SSL program. With your great attention to detail and input from the stakeholders we look forward to continued success with the Energy Star program. I wish I could have made it to your meeting last week, but unfortunately my schedule would not allow it.

Please find below some comments on the draft proposed for the Energy Star standard for the replacement lamp category. One form factor in the category, low voltage halogen replacement lamps, is an area where I have personally done extensive research for the last 2 years. As you may know, our first model LED MR16 was tested in the CALiPER program and did extremely well, achieving 159 lumens, 2800K, 96 CRI.

COMMENTS:

1) ANSI color bins: Our research into color perception has repeatedly shown that observers perceive LED light at 3000K as cooler than a halogen light at 3000K. An LED halogen replacement lamp that is manufactured to achieve 3000K with the intention to replace a 3000K halogen lamp will be met with resistance as the 2 lights will look very different. However, an LED lamp manufactured to a color temperature of around 2700K will look much more like a 3000K halogen lamp - assuming the correct bins around the blackbody curve are chosen.

While we recognize that you should stay with the ANSI color bins, we will have to do our best as a company to inform our customers of this difference in perception so they do not simply try to swap a 3000K LED for a 3000K halogen and then return the product for refund because they don't look the same - especially when they can get a solution that is much closer to what they want by ordering a slightly warmer CCT - perhaps the 2700K ANSI bin for instance. Since it is one of the objectives of this Energy Star standard to ensure that the replacement products will perform similar to the product they are replacing, we feel it necessary to raise this issue. The average homeowner will probably not be too concerned, but commercial businesses will most certainly be concerned about how their products and / or properties look.

2) On the issue of dimming and defining a standard protocol for compatibility I would like to propose that the DOE make special considerations for low voltage halogen lighting replacement products, and indeed it appears that you have already acknowledged this is necessary. This market segment has the unique challenge of requiring compatibility with both magnetic and electronic transformers and associated dimmers. We have found that only a thorough compatibility testing procedure is a reliable method of ensuring widespread compatibility with such transformers, and even then, does not ensure complete compatibility. We are constantly adding new electronic transformers to our test fixture as this is the only type that seems to present a challenge. Although

magnetic transformers do require compatibility testing, we have never seen any circumstance where they posed any challenges. A common issue with electronic transformers is the "minimum load requirement". While it appears possible to substantially address this requirement with appropriate driver circuit design, it does remain a challenge to completely eliminate all compatibility issues. For instance, one required test should be to test compatibility with not only a single unit connected to an electronic transformer, but also multiple units. We have tested configurations that worked when a single LED lamp was connected to an electronic transformer, but did not work properly when 10 or more LED lamps were connected to the same transformer which had sufficient rating to drive them. This was due to the fact that the input stage of the LED product used a common bridge rectifier configuration followed by a storage capacitor. The resulting current spikes, while not much of an issue other than the reduction of power factor, caused current spikes above the rated current of the transformer when many units were connected. It also resulted in excessive audible noise coming from the electronic transformer. The inverse has also been observed, where a single lamp connected to the transformer would not work, but multiple lamps did. The only solution is to test with 1, 2, 3, 4, n lamps connected to the transformer.

Dimming is also something that should be tested in a similar fashion. Manufacturers and test facilities can easily build fixtures that will allow them to "switch in" and / or "switch out" multiple types of electronic transformers, dimmers, and number of lamps under test - making it relatively easy to test compatibility with multiple different transformers, dimmers, and connected lamps. It is possible to dim an LED replacement lamp completely down to zero light output in the low voltage halogen replacement market. Our current production unit has had this capability since the beginning of 2008. Most low voltage LED replacement lamp products use buck converters to power the LEDs. When the input voltage drops below the LED string voltage, unpredictable flashing behaviour can occur. In addition, much of the dimming action occurs near the bottom end of the dimmer. At the very minimum, the dimming standard should indicate that the light should dim to 10% to 20% and not exhibit odd flicker / flashing behaviour.

It should also be noted that no LED low voltage halogen lamp should qualify for the Energy Star label if it cannot demonstrate compatibility with most electronic transformers. This type of transformer is used widely, and a properly designed product will generate flicker free light when used with most of these transformers.

3) To address variation from the ANSI standard shape, I propose a drawing on the outside of the packaging / sell literature showing the standard ANSI shape in one color, while the drawing of the LED replacement product is super-imposed on this drawing - clearly showing the consumer how the physical shape varies from the ANSI standard product.

4) Replacement LED lamps have the added challenge of being used in many different fixtures and applications. The designer of the product never knows if the lamp will be in an application that allows adequate air flow. We have observed many field failures of LED lamp products due to inadequate air flow because the replacement LED lamp was installed in a fixture / application that restricted air flow. As such, we feel it is absolutely crucial to include automatic temperature sensing circuitry that will reduce the power level

appropriately to keep the LEDs AND other components from overheating, keeping the junction temperature of the LEDs and all other components within operating specifications. This is very straightforward and easy to implement, requiring little more than a thermistor and perhaps a few resistors in most applications. The added cost is insignificant compared with the added robustness of the product.

5) 120 Hz ripple. It is common practise for LED replacement lamps to have 120 Hz ripple from the rectified incoming AC waveform due to the fact that many designs do not utilize storage capacitors at the input, resulting in a simplified design, high power factor, and reduced costs. While the 120 Hz ripple is not noticeable to most of the population, there is an underlying concern that should be addressed. Designers of replacement LED lamps may drive peak currents through the LEDs far beyond their rated current values in order to achieve the average power and light levels required for the application. They must do this in order to compensate for the "dead zones" where insufficient power is available on the incoming waveform. For example, if an LED is rated for 350mA and the designer wishes to achieve an average current of 350mA, the peak currents in some situations could reach close to 600mA. These large peak currents can cause current crowding, resulting in localized heating and damage to the die, while overall average power levels remain within specifications. Any specification for an LED replacement lamp using this type of driver topology should place an upper limit on peak drive currents. Input from LED manufacturers gathered to date suggests that momentary peaks of approximately 1.2 to 1.3 times the maximum rated current should not cause any damage, but levels above that amount could be cause for concern in long term reliability.

6) Long term reliability testing should be done out to at least 5,000 hours, and could apply to a family of products that use similar thermal management, drive electronics, and LEDs. Many products include electrolytic capacitors, which, if not properly specified, will show significant signs of degradation at this point. Such degradation would result in increased ripple currents, which would generally reduce light output. Semiconductor devices may also start to fail at this point as well if not properly chosen. Many devices will operate well beyond their design limits long enough to make it through an LM-79 photometric test, but experience large failure rates in the field within a few months. The only true way to test for such failures is long term testing on multiple units.

7) Maximum case temperatures on all components should be verified that they are within the manufacturers published specifications. In the world of solid state lighting their tends to be much focus on the junction temperature of the LEDs. There are many electronic components used in the driver circuits that are not capable of long term operation at the elevated temperatures that LEDs can reach. Their junction to ambient or junction to case thermal resistanc is too high. This is further exacerbated in LED replacement lamp applications where form factors dictate minimal available surface area for heatsinking, and close proximity between drive electronics and the LEDs / heatsink.

Best regards,

Scott Riesebosch
CRS Electronics
Your Partner In LED Research and Innovation