LEDs: Redefining the basic assumptions of lighting

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Over the past 150 years or so, the lighting industry has evolved into a mass production industry built around the concept of standardized bulbs, designed with built-in obsolescence. Consumers find themselves frequently replacing identical, short-lived products with more of the same. This trend is supported by a small number of large manufacturers that meet demand by building billions of identical products at low cost.

As the lighting industry transitions to LED technology, does this business model continue to serve its best interests? And does it leverage the fundamental advantages of solid state lighting?

Clearly, LEDs offer dramatic advantages in energy efficiency and operating life. By consuming as little as one-third the energy, LED light bulbs can deliver approximately the equivalent amount of light of traditional incandescent and fluorescent lighting. LED bulbs also promise to last more than 20X longer than products based on more mature technologies. Moreover, the solid state components of LED bulbs offer better protection against mechanical damage than relatively fragile traditional lighting technologies. Together, these characteristics offer users of LED lighting solutions a highly attractive ROI, particularly in commercial and industrial applications where maintenance and bulb replacement is difficult and/or expensive.

Perhaps just as important as the technology’s longer operating life, higher efficiency and more robust design, is the architectural flexibility that LEDs provide. For example, lighting designers may choose to employ point sources of LED light and distribute them around a shape, rather than concentrate the light source and use diffusers and shades to distribute the light where it’s needed. These unique characteristics give lighting designers tremendous freedom to deliver a light source in new and innovative ways. Product developers can craft LED lighting solutions into arbitrary shapes or embed the light fixture into building materials, walls or furniture. They can direct the light more accurately, or more easily control its intensity or

color to create dynamic lighting environments. Some manufacturers have already developed prototypes of windows that are transparent during the day and, via clever use of LEDs and materials with differing refractive indices, emit light at night.

Lighting appliances

By taking advantage of the longer operational life of LEDs and the technology's ability to be formed into a wide variety of creative shapes and sizes, designers may transform the lighting industry from a mass production business into a mass customization business. Rather than build an industry around standardized, frequently replaced light bulbs and fixtures, this new industry will offer product developers a broad selection of reference designs that take advantage of one or more of the distinct properties of LED technology. With the use of intelligent, automated design tools, manufacturers will be able to quickly develop highly customized lighting solutions to meet the individual needs of each customer. In this new business model where lighting is no longer disposable and lasts for more than a decade, beautiful light sources can be embedded into the structure of a commercial or industrial building or into the furniture of a residence, and will be sold as appliances that are designed to last until the building or home is remodeled.

To achieve this goal, designers must take a systems approach. Early failures in the first generation of LED lighting systems have proved one point: The longevity of any LED-based lighting solution is driven by the individual component with the shortest operational life. While the typical LED circuit meets Energy Star SSL V 1.1 L70

requirements for approximately 45,000 hours of operation, the lifecycle of the average two-stage power supply used to power that circuit lasts only about 20,000 hours. In effect, weaknesses in the power supply design are undermining the long lifetime benefits and ROI of LED technology.

Eliminating points of failure

Why? Many LED lighting systems today use a classic two-stage power supply that combines a first-stage boost converter for power factor with a second-stage high voltage DC-DC converter. The most common failure point in those supplies is the electrolytic capacitor used for bulk storage between the two stages. Operating continuously at full load and typically placed in a tightly enclosed space such as a ballast brick or bulb base with heat-generating power supplies and high brightness LEDs, these bulk electrolytic capacitors must endure harsh thermal conditions. Eventually the capacitor's dielectric material degrades and the device loses capacitance and fails. While the controllers and other semiconductors used in LED lighting solutions last more than 100,000 hours and diodes, transistors and ceramic capacitors last almost as long, the electrolytic capacitors embedded in most two-stage power supplies used in the lighting industry today exhibit an operational life of only about 20,000 hours.

These thermal management issues are especially critical given one glaring weakness of LED technology: While bulbs using traditional technologies can dissipate excess energy in infrared form, LEDs must dissipate excess heat into their heat sinks. This amount of heat can easily reach excessive levels, particularly when the lighting solution is compressed into a small bulb base. Carefully managing these thermal issues is especially crucial in LED designs because higher ambient temperatures can both drive up LED junction temperatures, affecting light output, and shorten LED operating life.

One way to address this problem is to build LED lighting solutions with power supplies that use a topology designed to eliminate both vulnerable electrolytic capacitors and unreliable opto-isolators used in isolated flyback designs. A new generation of single-stage power LED drivers addresses this need by eliminating these potential points of failure. By replacing electrolytic caps with highly stable ceramic caps, these power supplies can closely match the longer lifecycles of LEDs. In addition, by operating at efficiency levels in excess of 90 percent while exceeding Energy Star requirements for PF and THD, these highly integrated converters generate less heat and, in the process, help simplify thermal management issues in highly compact lighting designs.

Conclusion

Clearly, LED technology's unique design advantages in terms of flexibility, energy efficiency and longevity, offer lighting manufacturers an opportunity to revolutionize their industry. To maximize these advantages, however, designers must approach the LED and its power supply as a single appliance. By carefully considering how each design component impacts heat distribution and how environmental conditions can be better controlled, lighting developers can transition their industry to a new phase where LED-based solutions become a truly integral element in building and residential architecture.

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