Solid-State Lighting

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The lighting industry is in a state of flux. Change will mean obsolescence for many lighting technologies of today, including the majority of solutions currently being developed that use today's best LEDs. Current state-of-the-art solid-state lighting will be insufficient for future demands. Rather than look at LEDs as a technology that need not be replaced, today's designers must consider that aspects of these products will certainly be outmoded tomorrow, particularly the LEDs themselves. 2003 components and solutions are no longer efficient or innovative enough. It will be no less true for 2009 products in 2015. The changing criteria for LED lighting will greatly impact the implementation of LEDs in the next decade. While LEDs will fall behind their own descendants, other elements of solid-state lighting can tap more mature technology that can have a greater, longer lasting impact. As lighting shifts from filaments to diodes, development must shift its approach from analog to digital. LEDs will enable lighting to evolve into an extension of our electronics-oriented world. Analogies can be drawn between the future of LEDs and the recent past of electronics such as computers and personal devices solid-state lighting will undergo massive changes in terms of interoperability, miniaturization, and desirability. As LED designers, we must revise our use of the electrical, mechanical, and optical technologies that currently govern lighting designs with an eye for producing products that will remain viable longer and accelerate LED adoption.

Interoperability: Electronic Lighting

Since light emitting diodes are uniquely electronic themselves when contrasted with nearly all other lighting technologies, they have exceptional capacity for integration into and use of electronic systems. Tomorrow's lighting systems will be interactive to greatly enhance their efficiency. They will retain today's universal control on a single circuit and gain targeted control down to individual luminaires. The National Electrical Manufacturers Association (NEMA), partnered with the California Energy Commission, has established Standards Publication 243 to govern an open digital communication protocol for lighting systems. [1] The standard allows lighting products to be plug n' play as though they are computer peripherals. LED designers should lead the way in adopting this open directive and reduce today's impediments to LED adoption. The cost of solid-state lighting is friction enough for now.

Unlike this typical fluorescent solution, tomorrow's lighting systems will have enhanced targeted control down to individual luminaires that will dramatically reduce power consumption.

NEMA 243 has been established to govern systems regardless of lighting technology, but LEDs present unique opportunities to dynamically adjust brightness and improve efficiency further. Since LEDs excel when pulse-width modulated in fact, they gain in efficiency and reliability additional layers of electronic control can be more seamlessly incorporated within the guidelines of NEMA 243 without sacrificing performance or product life. When systems allow individual luminaire control, designers should incorporate ambient light sensors and occupancy sensors to automatically maintain fixed illuminance or dim the lights when the space is not in use. The sensors should be part of the luminaire itself. The users of each luminaire will also have local, manual control of illuminance depending on their task. The ergonomic benefits may be profound. Reading and writing on paper demand greater illuminance to prevent eyestrain, whereas working in front of a computer screen demands less light and greater contrast.

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Miniaturization: Mechanics of LEDs

One of the benefits of increased efficacy will be a reduction in the demand for thermal management to sustain LEDs. For most lighting applications, the physical size means that LEDs are not in close enough proximity to require premium thermal management. Ultimately, the reduced thermal demand will allow the cost of these types of LED fixtures to decrease significantly. The relative cost of LED fixtures can be on par with other technologies, and improvements in cost may be possible because the large reflectors required for bulbs and tubes are replaced by small, plastic optics on LEDs. For most lighting, thermal management has become a less important part of the conversation. Designers should not dedicate system cost to an element with decreasing significance.

On the flip side, the escalating efficacy of LEDs makes their use possible where very small, high-intensity light sources are desired. For those applications where high optical and thus thermal density are needed, LEDs are a burgeoning option. As efficacy increases, smaller fixtures will be possible even where they are not explicitly required. For large-scale lighting, the potential cost savings gained by shrinking the fixtures should be considered as compared to the thermal and reliability benefit of a larger product.

OPTEK Technology's Optimal XIV Star Series, miniature half-watt LED package and LED module strips are just a few of the LED devices being employed in indoor and outdoor architectural lighting applications.

LED fixtures need to account for the given that LEDs manufactured today will quickly lag behind their future counterparts. LED replacement is thus a necessary aspect of the design. There are cons to making LEDs easily maintainable. Thermal design is constrained since a near-permanent mechanical attachment produces the best thermal path. Likewise, most optical designs are at least semi-permanent or lack distinction between an LED module and an optically functional enclosure. Ideally, the least amount of care and effort is required and the greatest portion of the fixture is retained when replacing degraded or obsolete LEDs.

Desirability: LED Aesthetics and Optics

Over the next several years, efficacy will increase and, more importantly, cost per lumen will be driven down, but these changes will be less significant than gains in control of chromaticity. As efficacy increases, its significance as a factor in design shrinks. Concerning aesthetics, uniformity of color temperature is king. The tools that will improve uniformity are now in their infancy. In the last year, ANSI C78-377 was released, setting today's bar for uniform color. [2] Designers have the tools to meet these requirements because most LED manufacturers have reduced the chromaticity range of their base-cost distribution to meet the new standard. Despite these improvements, manufacturers that use routine, single-reel manufacturing may fail to deliver adequate uniformity because today's component distribution is still too large to ensure that each fixture is indistinguishable from the next. Routine manufacturing will also generate products with greenish or pinkish color due to chromaticity sufficiently distant from the black body curve. By employing multiple-bin assembly

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practices, designers can eliminate both concerns. Most LED manufacturers provide enough binning to populate fixtures with nearby bins above and below the black body curve and left and right of the targeted net color temperature. In the next decade, LEDs will be expected to generate uniformity that outpaces the rest of the lighting industry, but there is no need for integrators to wait for the component manufacturers to deliver the solution.

Efficacies today are generally given based on total flux produced rather than flux delivered. Total luminous flux provides a reasonable idea of light delivered in legacy technologies that emit in nearly all directions and rely on reflection and scatter, but it misrepresents the utility of focused sources. LEDs may not currently match the total efficacy of fluorescent bulbs, but their potential efficiency at lighting a targeted area more than makes up the difference. Consider one of the most common lighting applications: a typical office or cubicle has roughly 10 square meters of task area with a requirement of 30 lux delivered to the work area, and 10 lux washing the walls. [3] From an ideal point source with an ideal optic that completely conserves étendue the throughput of light from its source to its intended target the total delivered luminous flux need only be approximately 600 lumens. Though LEDs are not ideal, their source is small enough that the fixture will not require excessively large optics to deliver net throughput above 50%. Using components with source efficacy around 70 lm/W, the total power consumption can be on the order of 20W and net target efficacy is 30 lm/W. Contrast that result to the performance of a typical fluorescent solution for a small cubicle a troffer with two T-8 tubes and total power consumption of 60W. Fluorescent source efficacy might be 100 lm/W, but the net optical efficiency is less than 20% and the target efficacy is only 10 lm/W. For LED designers, the challenge will be to provide solutions that enable installers to reasonably optimize the lighting for massively diverse applications.

Conclusion

Changes in electrical, mechanical, and optical characteristics of LED design provide the path for achieving greater interoperability, miniaturization, and desirability of solidstate lighting products and solutions. Today, marketing claims focus on the long-life—often proclaimed as indefinite life of LEDs, but today's designs should embrace the fact that the components will need to be replaced. Designs that will outlast the LEDs powering them are certainly achievable today if those aspects of lighting that are currently evolving are taken into account. By aggressively applying a standard for controlling lighting both universally and individually NEMA 243—LED fixtures will lead the way into next generation lighting. It will not be photon production that makes LEDs best suited for NEMA 243 operation; the key difference will be coupling their electronic nature with electronic control. Gains in efficacy curtail concern for thermal management, and emission from a near point source allows for small, efficient optics. Coupling these new advantages, designers will shrink light sources, eliminating reflectors. Burgeoning advances in chromaticity distribution and optics make it possible for LEDs to produce aesthetically-pleasing light and efficiently deliver the required lumens without generating and scattering excess photons. Lighting will shed many of its preconceived expectations during the next decade, and solid-state lighting design is ready now to meet the coming demands. The designs that will carry well into the next decade will only be those that are intended to do so.

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