

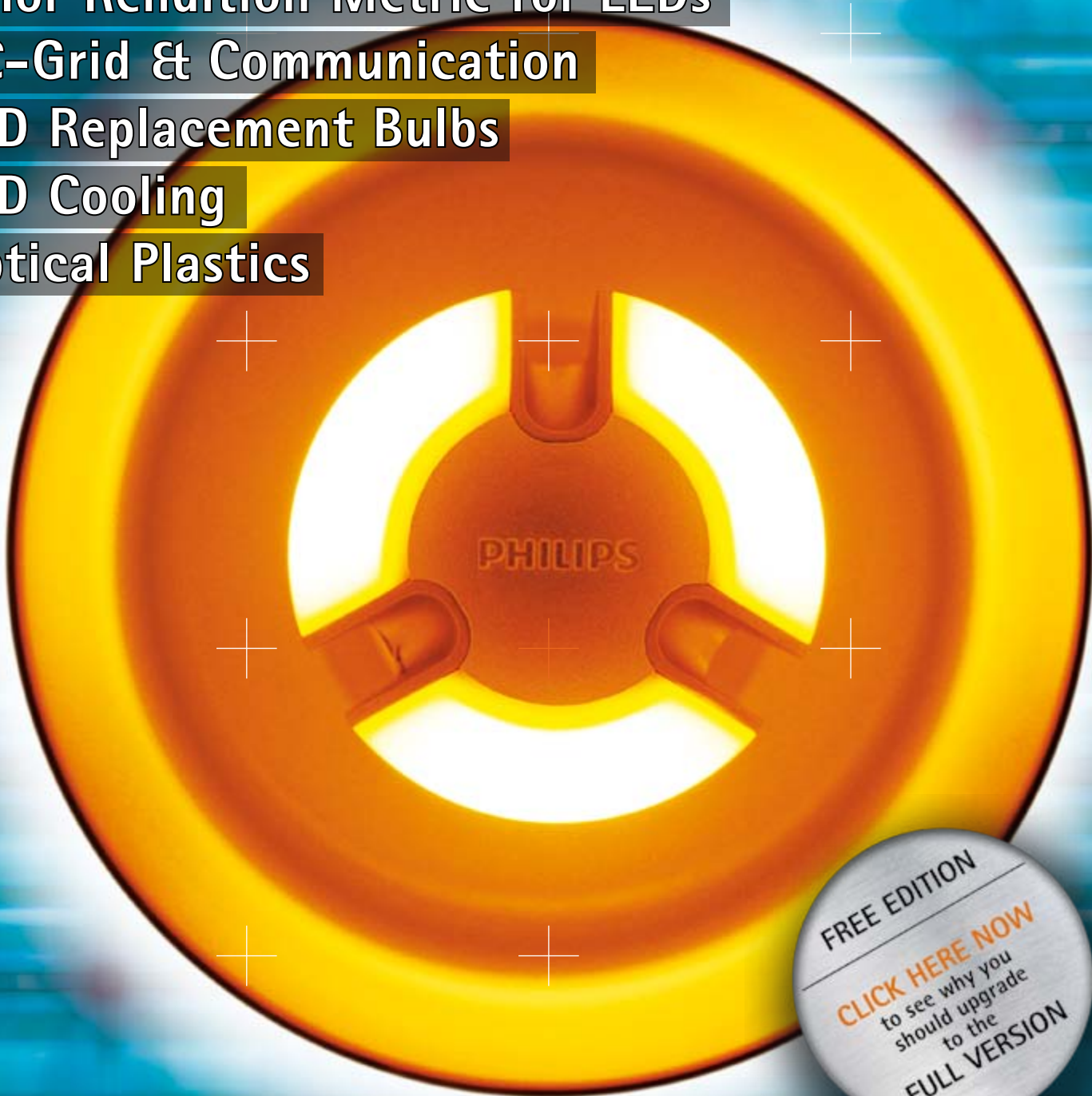
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Powerful Trends in LED Lighting

At the time of writing this editorial, all of the LED professional staff is shocked about the aftermath of the earthquake in Japan. However, I feel confident that our readers will do what they can to help the Japanese people in this difficult situation.

The concept of saving energy takes on a new dimension when recognizing the dramatic development of energy generation. For this reason I would like to suggest that we continue to contribute to energy saving with Solid-State-Lighting.

Lately, a lot of new LED lighting innovations have been announced – innovations which will push the LED business into an even stronger position.

In the near future the costs of LEDs will come down due to improved production methodologies and material improvements. LED manufacturers are stepping up their production output significantly by converting the chip manufacturing facilities to 6-inch, 8-inch and 12-inch wafers (e.g. Rubicon, Monocrystal). Bridgelux and NeoPac demonstrate their GaN-on-Silicon technology. This cost-cutting technology (70-80 % cost reduction) could be optimized for 8-inch Silicon wafers and will make LED manufacturing compatible with existing automated semiconductor lines. And last but not least, using new, high-speed in-line production test equipment for defect inspection of whole and diced wafers will increase the production quality and reduce testing costs (e.g. KLA-Tencor).


On a product level we acquire significant improvements. The new Luxeon S from Philips Lumileds is manufactured using an alignment process between 9 LED dies and a respective selected phosphor for reaching the specified target values of the emitters. This production process enables freedom from binning by reaching a color distribution area within a 3 step MacAdam Ellipse. Freedom from binning is relevant in many areas such as logistics, maintenance and ease of use in general.

Leading manufacturers are now also starting to measure, specify and deliver performance data of LED light engines at higher temperatures, e.g. at 85°C (Cree, Philips Lumileds). In fact, these data are more practical than the 25°C test-data which are commonly used nowadays. Hopefully, more manufacturers will also follow this procedure with a standardized measurement metric.

The LED professional Symposium +Expo 2011 (27-29 Sept.) is really gaining momentum. You will leave this event with insights into LED lighting provided by first-class presentations. You will meet the Leaders in LED lighting in an extraordinary exhibition area in the Bregenzer Festspielhaus (James Bond film location) and you will be able to discuss your topics with the experts. A great chance to build and expand your networks! Take advantage of the Early Bird bonus and reserve your ticket now. You should also book one of the limited seats for the workshop and the gala dinner before they are sold out (www.led-professional-symposium.com). We are very excited about the chance of meeting you personally in Bregenz and supporting you with the winning approaches in LED lighting.

We would very much appreciate your feedback about *LpR*. Let us know what you like or tell us how we can improve our services. Please keep in mind that you are also welcome to contribute your own editorials.

Yours Sincerely,



Siegfried Luger
Publisher

Content

■	Editorial	p 1	News - PROJECTS	p 4
	Imprint	p 60	News - PRODUCTS	p 6
			News - RESEARCH	p 25

■	INTERVIEW			
	"The Optical Plastics Make a Difference to a Lens"	p 28		
	Interview with Peter Jackson and Tsuyoshi Okii from Styron LLC			
	by Arno Grabher-Meyer, LED professional			

■	APPLICATION			
	Active Cooled 75 to 100 W Equivalent LED Retrofit Bulbs	p 32		
	by Istvan Bakk, Tridonic, and Brandon Noska, Nuventix			
	Re-Thinking a New Power and Control System for LED Lighting	p 38		
	by Mark Covaro, Redwood Systems			

■	CHARACTERIZATION			
	Advanced Lighting Technology Needs an Advanced Color Rendition Metric	p 44		
	by Artūras Žukauskas, Rimantas Vaicekauskas, Vilnius University, Michael Shur, Rensselaer Polytechnic Institute			

■	ELECTRONICS	p 50		
	Sophisticated LED Driver Enhances Quality in Full Color Video Displays			
	by L. Pistoni, M. Merisio, F. Lissoni, and W. Trovo, ST Microelectronics			

■	THERMAL	p 54		
	Cooling High Power LEDs			
	by Norbert Engelberts, Advanced Thermal Solutions			

Advertising Index

LED professional Symposium	p C2
Cree	p 3
Lambda Research	p 5
Edison	p 7
LEDLink	p 11
Kingbright Electronic Europe	p 13
Micrel Inc.	p 15
Renesas	p 19
Infineon	p 24
Signcomplex	p 26 p 45
Instrument Systems	p 27
Excelitas	p 31
Everlight	p 37
LED Lighting Taiwan	p 39
Future Lighting Europe	p 39
LightFair International	p 43
Guangzhou Int.I Lighting Exhibition	p 49
LED Lighting Summit	p 53
Green Lighting Shanghai	p 55
Macroblock	p 57
Stellarnet	p 59
Citizen	p C3
Osram	p C4

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Lighting in this image depicts applications using Cree XLamp LEDs. Cree, XLamp and the Cree logo are registered trademarks, and Lighting The LED Revolution is a trademark of Cree, Inc.

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New Energy-Efficient Lighting Saves EUR 10,000 per Year at Nature Museum

Thanks to a new, energy-efficient LED lighting solution by Zumtobel, the Inatura Nature Museum in Dornbirn/Austria has moved into a new lighting era. The museum's previous lighting system, using conventional spotlights, has been replaced by advanced, energy-saving LED spotlights. With its compact, clear design, the Supersystem lighting system blends perfectly into the museum architecture. Inatura's new lighting solution features 3-phase LED units, each including 3 LED spots with 2.6 W each, which have been installed in the entrance area as well as in large sections of the exhibition area. The client opted for Supersystem mainly because the old spotlights could simply be disassembled, allowing Supersystem units to be installed in the track system in place.

Facts and Figures:

Client: Stadt Dornbirn, Dornbirn/A

Lighting solution: Zumtobel

New since 2010:

Supersystem LED lighting system

Zumtobel lighting solution already in place:

Cardan Spirit lighting system,

Slotlight light line



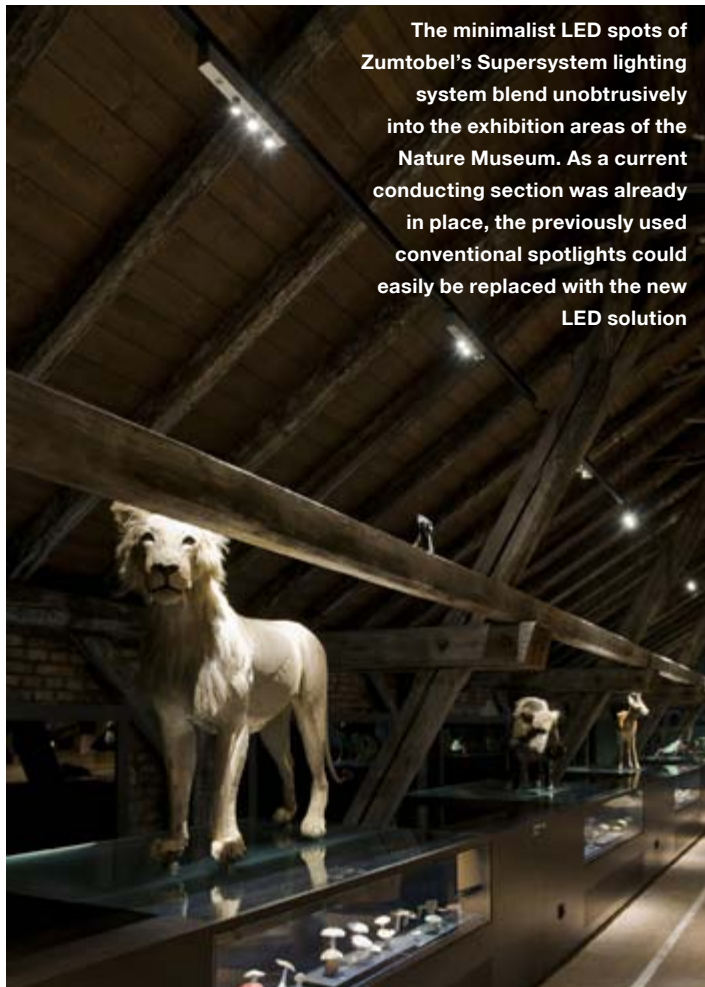
At Inatura, the newly installed Supersystem lighting system cannot fail to impress with its compact spotlight design and superior lighting quality

"For Inatura, the new multifunctional LED lighting system by Zumtobel opens up exciting new perspectives: the lighting quality for our exhibits is significantly increased, and many exhibits are literally shown in a new light.

Moreover, this highly energy-efficient system allows us to save energy costs of approximately 10,000 Euros a year", explains Peter Schmid, Managing Director of Inatura.



The high lighting quality provided by LED luminaires ensures that focussed light is directed to where it is needed



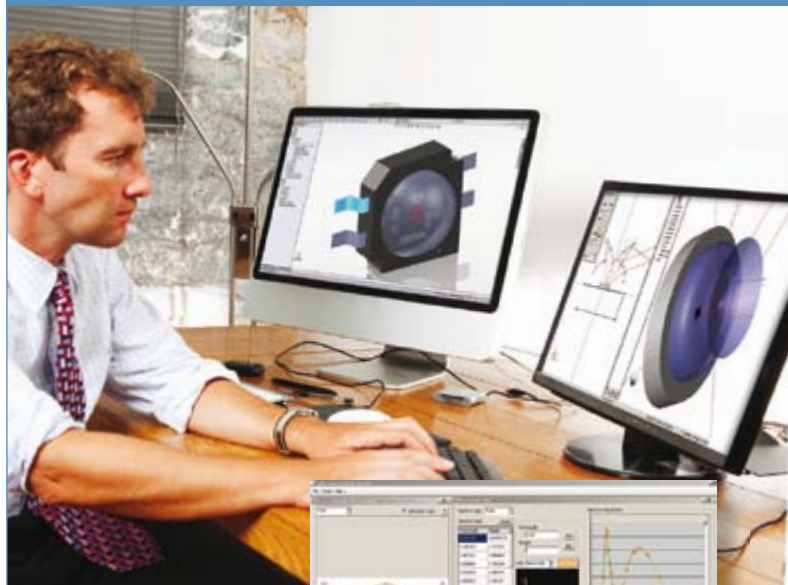
The minimalist LED spots of Zumtobel's Supersystem lighting system blend unobtrusively into the exhibition areas of the Nature Museum. As a current conducting section was already in place, the previously used conventional spotlights could easily be replaced with the new LED solution

The LED-based Supersystem lighting system by Zumtobel cannot fail to impress on account of its resource-efficient use of materials in combination with lighting comfort of outstanding quality. With a service life of approx. 50,000 hours, its extremely compact LED spots allow for energy-efficient illumination and are particularly suitable for accent lighting of exhibits. A variety of spotlight models, a wallwasher and the option of integrating indirect lighting make Supersystem the number one for sophisticated lighting tasks. High-quality reflector technology ensures uniform illumination without any flaring effects. In museums, art galleries and exhibition areas in particular, Supersystem allows to create lighting solutions which provide maximum enjoyment of art by subtly illuminating art objects and sculptures.

The new lighting solution is a donation in kind by the Zumtobel Group for use in the new "Science Center", which is intended to give children, youths and adults a better understanding of technology and the sciences through fun, games and interaction. Energy is the main theme of the so-called "Science Zones" and also covers the field of "Light and optics".

"The Science Center addresses mainly children and youth, making an important contribution to their technological education and empowerment. For us as a leader in innovation, it was only logical to support this project. Having provided a donation in kind, we are now also in a position to demonstrate - here at our group's head office - Zumtobel's lighting competence to our customers and employees via an excellent application", explains Harald Sommerer, Chief Executive Officer of the Zumtobel Group. ■

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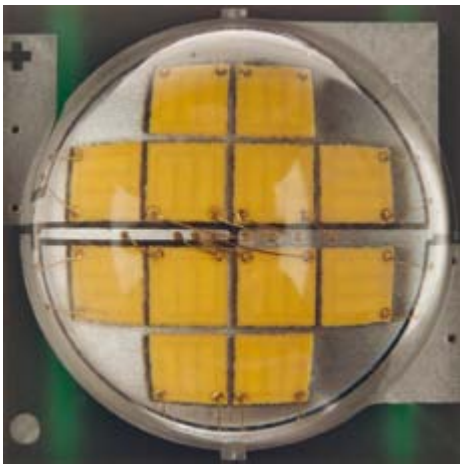


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New Cree XLamp® MT-G LED Delivers Unprecedented Performance

Cree, Inc., a market leader in LED lighting, announces a new lighting-class LED designed for high-output, small form-factor directional lighting applications. The XLamp MT-G LEDs are optimized for 35 W-50 W halogen MR16 retrofit bulbs and other accent, track, display and down lighting used in retail stores, residential settings, museums, art galleries, hospitality and landscapes and are the first commercial LEDs to deliver sufficient light output for these applications.



Cree's new XLamp MT-G LEDs enable customers to address high-output halogen retrofits

The multi-die XLamp MT-G LED features Cree EasyWhite™ technology to deliver consistent color in a small, highly efficient package. This innovative LED is designed for the high-lumen, small-footprint requirements of 35 and 50 Watt halogen retrofit lamps. Cree engaged driver, thermal and optic providers to create an MR16 lamp reference design to further enable its LED customers to quickly address this market. The reference design is available for free at mtg.cree.com.

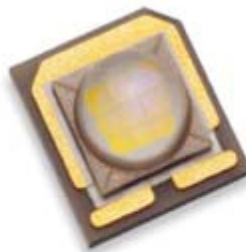
"To date, there are no energy-efficient alternatives for many high-lumen, small form-factor, directional lighting applications. Until now, LED-based MR16 lamps have been a tremendous challenge for the lighting design community in terms of both light output and color consistency due to their small size and limited capacity for thermal management," said Paul Thieken, Cree, director of marketing, LED components. "Cree developed this LED

from the ground-up with applications like these in mind, and its introduction signals the arrival of the LED lighting revolution in these high-profile markets."

The XLamp MT-G LED is the first in the industry binned and tested at 85 degrees C which can simplify luminaire design calculations and speed time-to-market. With a 9mm x 9mm footprint, the MT-G LED delivers up to 560 lumens at 1.1 A at 85°C or up to 1525 lumens at 4 A at 85°C in warm white (3000 K). Samples are available immediately and production volumes are available with standard lead times. ■

LUXEON S Delivers Punch, Color Quality, and, as First Product, Freedom from Binning

LUXEON S making its debut this week stands to change expectations of what's possible with the latest generation of LUXEON LEDs from Philips Lumileds. Designed with retail spot and down lighting in mind, LUXEON S enables simple, effective, and efficient lighting. Retail lighting is intended to highlight the most important products, make merchandise stand out and shine, and create an environment that entices and comforts shoppers. LUXEON S supports all these objectives and reduces energy consumption and costs.



Color Consistency:	
• LUXEON S (Hot)	Within 3 SDCM
• CDM	Within 4 SDCM
Light Output:	
• LUXEON S (18W) (Hot)	1300 lm
• LUXEON S (9W) (Hot)	790 lm
• 50W Halogen	~770-900 lm
• 75W Halogen	1250 lumens
• 20W CDM	1300-1800 lm
Efficacy / Efficiency:	
• LUXEON S	(Hot) 72-88 lm/W
• 50W Halogen	15-25 lm/W
• 75W Halogen	17 lm/W
• 20W CDM	65-80 lm/W
Compared to halogen and CDM:	
• Superior efficiency	
• No heat in the beam	
• Better dimming	
• Instant start-up	
• Longer lifetime and lower maintenance	

Light Source Comparison (LUXEON S is 'hot' tested and binned at 85°C)

Lines. "The design of this product from the Thin Film Flip Chip and Lumiraminc phosphor to the tight alignment between the 9 LED die in the package contribute to the color performance, industry leading flux density, and punch unique to LUXEON S. In addition, by hot testing at 85°C and achieving Freedom from Binning, we continue to move closer to the lighting industry in language and expectations for LUXEON performance."

The color quality and beam uniformity from LUXEON S is unsurpassed by any other comparable LED available today. It's the first Freedom from Binning LED from Philips Lumileds, meaning that there are no color bin selections to be made. With a correlated color temperature of 3000 K and a CRI >80, all LUXEON S emitters are targeted to the black body curve and populate an area within a 3 step MacAdam Ellipse. The result is unmatched uniformity and consistency within the light beam and between emitters.

The 1300 "hot" lumens LUXEON S delivers come from a very small optical source that enables a 10° beam from a compact reflector less than 50 mm in diameter. In a retail spot or down light the result is tight, sharp beams that deliver high Punch – high center beam intensity with beam uniformity and a crisp single shadow – that highlights and gives depth to objects that are being illuminated. LUXEON S makes its debut at the Strategies in Light and Euroshop conferences this week. At EuroShop, LUXEON S will be shown in Fortimo solutions from Philips and others with solutions targeted at the retail and hospitality lighting segments.

"LUXEON S breaks new ground not just for Lumileds but for the entire LED industry," said Frank Harder, VP Marketing LUXEON Product

LUXEON S is available immediately for prototyping and development. Contact a local account manager for more details. ■



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New Bridgelux LED Arrays Double Light Output

Bridgelux Inc., a leading developer and manufacturer of LED lighting technologies and solutions, announced the expansion of its award-winning RS LED Array portfolio to include the industry's highest performance LED products designed for very high lumen applications such as retail shop lighting, high-bay, roadway, exterior area and industrial lighting applications.



Bridgelux's new LED arrays allow a rapid development of new high-lumen LED products

The new RS Arrays deliver 3500 to 8000 operational lumens, an extended range of color temperatures including warm, neutral and cool white (2700K to 5600K), and multiple color rendering indices (CRI) options.

Shattering industry standards for light output performance while significantly improving efficacy and further reducing the cost of solid-state light (SSL), the new RS Arrays deliver 3500 to 8000 operational lumens, an extended range of color temperatures including warm, neutral and cool white (2700 K to 5600 K), and multiple color rendering indices (CRI) options, further increasing choices for high quality lighting. These LED arrays both simplify and enable rapid development of new high-lumen LED products accelerating the ability for solid state lighting to replace high wattage HID luminaires, providing safer operation and reducing payback periods to as little as 2 years. These high flux density sources enable precision lighting previously impossible with lower power solid state lighting technology, opening up new markets to solid state lighting.

"With the new RS Arrays, Bridgelux continues to advance its reputation as a manufacturer of high quality, leading-edge LED lighting solutions for a broad range of indoor and outdoor applications," said Jason Posselt, vice president of global marketing.

"Leveraging the significant success of previous product generations, the RS Arrays are uniquely designed to help our customers quickly and cost-effectively introduce new products targeting an increasing number of lighting applications."

"As we initiated the design of our NEVALO SSL System for interior lighting applications the new additions to the Bridgelux RS Array series provided the best solution for the high light density versions of our new lighting module, launched," said Bruce Pelton, chief technology officer for the Tyco Electronics Lighting Division. "The Bridgelux team not only worked with us to meet our initial LED light source requirements but also demonstrated a product roadmap to provide an increasingly broad range of light output, CRI and efficacy options to meet the future requirements of our lamp and luminaire customers." ■

Sharp Boosts Power of Zenigata Series: New Mega Zeni & Mini Zeni

The new 15 and 25 W Mega Zeni models from Sharp are compact, lightweight, economical and extremely bright, whilst still providing a very high level of light quality. The new models produce a light output of up to 2550 lumen (depending on the module), a luminous flux of up to 102 lm/W and a long service life of 40,000 operating hours at a service temperature of 80°C.

The 15 W Mega Zeni modules are operated using a forward voltage of 37 V and a forward current of 400 mA. With the 15 W Sharp Mega Zeni series, the round LED matrix consists of a total of 96 LEDs that are arranged in eight parallel-switched series of twelve. The luminous flux is between 1350 and 1520 lm (4000 K 102 lm/W).



Sharp's new MegaZeni LEDs with 15 and 25 W are highly efficient with at least 88 lm/W for warm white versions up to 102 lm/W for neutral white versions and a reasonable CRI of 83

The 25 W Mega Zeni modules also have a forward voltage of 37 V but are operated using a forward current of 700 mA. With the 25 W series the round LED matrix consists of a total of 168 LEDs that are arranged in fourteen parallel-switched series of twelve. The luminous flux is between 2300 and 2550 lm (4000 K 98 lm/W).

The serial and parallel array of the LED matrix ensures fail-proof operation while offering the lowest possible thermal emission. The flat surface of the ceramic plate and the soldering points already in place make it possible to attach the modules to a suitable heat sink without too much effort or additional connecting material, thus guaranteeing excellent heat dissipation.

The color temperature of the new white light LED lighting modules lies in the range of 2700 to 4000 Kelvin. With regard to the CRI values and the color temperatures, the Mega Zeni LED modules correspond to the requirements of the international Energy Star program. They can be fitted in new LED lighting systems as well as in places where light sources were previously used.



Sharp's new 10 W Mini Zeni series radiates with even more efficiency, whilst retaining very good light quality (CRI values of up to 87) and a long service life with its compact and cost-effective design

The 10 W Mini Zeni models have the following features: They are operated using a forward voltage of 19.6 V and a forward current of 480 mA. With the 10 W series, the square LED matrix consists of a total of 60 LEDs that are arranged in ten parallel-switched series of sixes and achieve a luminous flux of between 610 and 690 lm. The serial and parallel array of the LED matrix ensures fail-proof operation while offering the lowest possible thermal emission. The flat surface of the ceramic plate and the soldering points already in place make it possible to attach the modules to a suitable heat sink without too much effort or additional connecting material, thus guaranteeing excellent heat dissipation.

The color temperature of the new white light LED lighting modules is in the range of 2,700 to 6,500 Kelvin with the shades "Warm White", "Natural White", "Pure White" and "Cold White". All models of the 10 W Mini Zeni series have very high CRI values of up to 87 and thus ensure color fastness and are true to detail. With regard to the CRI values and the color temperatures, the 10 W LED Mini Zeni modules correspond to the requirements of the international Energy Star Program, which specifies a CRI value of at least 80.

With the introduction of its LED lighting modules, Sharp is providing numerous marketable solutions for the use of LEDs as light sources for lamps. The luminous 10 W Mini Zeni LED modules from Sharp are suitable for a range of applications both indoors and outdoors.

For a long time it was not possible to replace traditional 50 W light sources with an LED module. With the 10 W Mini Zeni variant, Sharp is now able to introduce to the market a new alternative as a solution to this problem. ■

Everlight Electronics Announces High Voltage LED Series

Everlight Electronics Co., Ltd. launches a range of High Voltage LEDs especially suited for use in solid state lighting integral lamps, aka retrofit lamps.

Everlight's new HiVo series comprises a 1W, 2W and 4W solution. The single chip LED provides a luminous flux of 80 / 100 lm at 48-55VDC in a color temperature of 3000 /

5700 K. The 2W product with two LED chips connected in series achieves 140 lm for 2700 K at 95-111 VDC. The 4 chip LED with 275 / 375 lm for 3000 / 5700 K is available for voltages of 95-111 V in North America and Asia and 190-220 VDC in Europe. All HiVo components are supplied in a ceramic package with dimensions of 3.5x3.5mm for the 1W and 6.0x6.0 mm for the 2 W and 4 W.



Everlight's new HiVo series comprises a 1 W, 2 W and 4 W solution

The closer the HiVo LED's voltage is to mains RMS voltage, the fewer the components needed in the driver solution. Because the HiVo LED's voltage closely matches the mains RMS voltage, the need for a converter in the driver solution is completely negated. When Everlight's new HiVo LEDs are implemented into an LED Integral Lamp the full driver solution is no longer needed. Only a bridge rectifier, resistor, and capacitor are needed for very basic operation, resulting in higher overall efficiency of and a decrease in bill of material costs for the LED Integral Lamp.

Both the omission of often more fragile driver components and an improved thermal performance of Everlight's new HiVo LEDs, due to their ceramic packaging, result in better LED lifetime. Added space also allows the HiVo LEDs to be easily implemented into very small bulb applications like candelabra, MR11, or some MR16's.

In addition to cost reduction and efficiency improvements, fewer components in LED retrofit applications also mean fewer components to be manufactured and fewer steps in the assembly process – which drastically reduces the carbon footprint.

Everlight is fostering closer working relationships between our R&D, Sales and Marketing teams to meet and exceed our customer's expectations in both product offering and technology. The HiVo Series is expected to satisfy the fastest-growing global LED retrofit bulb market. ■

Seoul Semiconductor Accelerates Its Penetration into the SSL Market

Seoul Semiconductor, one of the world's leading LED manufacturers, released two new high-brightness LEDs, the 'Z6' and 'Z7' to its Z-series family and unveiled a plan to release one or two new product(s) every month to meet the increasingly diverse customer needs and demands brought about as LEDs proliferate the general illumination marketplace this year.



The Z-Power LED Z7 is a white 4 W-LED with 440lm at a CCT of 5,500 K



The Z-Power LED Z6 is a RGBW LED with a total power consumption of 4 W

The Z-Power LED Z7 series (4 W) is a high-brightness white LED constructed on a special ceramic PCB. It offers 440 lm brightness at 5,500 K color temperature. In particular, the Z series offers compact LED placement in a 9x7x3.2 mm package for designing high brightness solutions in demanding indoor and outdoor lighting products.

The Z-Power LED Z6 series has individually-addressable 1 W, red/green/blue and white LED die which can create full-color LED products. If all die are operated at the same time, the white color (4 W) can be created in a

diverse range of color temperatures (pure, warm and neutral). In addition, the Z6 series offers more flexibility to the designer with independent circuits controlling each of the four LED chips inside the package.

The Z6 series, which is available in an ultra-small package (9x7x1 mm), is specially designed to create dynamically colored lighting such as landscape lighting, stage lighting and digital signage with full-color performance. The Z6 series has superior color mixing properties compared to rival products and is scheduled to be released at a 30% less expensive price point making it a great addition to the solid state lighting (SSL) marketplace.

Brian Wilcox, the vice president of sales from Seoul Semiconductor, said, "We expect to impact new technological and economic inflection points in the LED lighting market with the new Z-Power LED Z6/Z7 series." Samples for both the Z6 and Z7 series are available now, and mass production began in February. ■

Xicato Extends the Spot Module Range: Up to 100% Flux Increases with 50% Efficacy Improvement

The Xicato Spot Module range, firmly established for accent lighting over the last two years, now has arrived into general lighting territory with range improvements encompassing up to 50% efficacy increases and range extensions that include a doubling of flux to 2000 lm.



Xicato has extended the Xicato Spot Module range to move into the general lighting arena

All modules have the same form factor with the same interfaces. For example, if a module has 400 lm or 2000 lm the 22 mm diameter aperture remains the optical interface and therefore no change in optics is needed. There is even backward thermal compatibility within the range. For example, the 1300 lm module (which can perform on a par with a 20 W CMH lamp) can be used on a heat sink designed for a 1000 lm module, preventing the need for luminaire design changes. Future proofing is a hallmark of this design concept.

Efficacy increases of up to 50% have led to the launch of luminaires complying with stringent efficacy limits (for example the UK Building Regulations Part L with its 55 lm/W at system level requirement in some areas) without any compromise in light quality: with color point stability, color rendering or evenness in intensity distribution. Producing these efficacies in such a small form factor and within the context of such a stringent light technical specification, including the industry best, sustained, color point tolerance is unique in the lighting industry.

Higher lumen packages of up to 2000 lm can now address general lighting applications and compete with 2 x 18 W CFL down lighters in attractive office, hospitality or public areas. Also effective Accent Factors even with background illumination levels of 750lux become possible in retail applications.

These 1300 and 2000 lm Xicato Spot Modules, with CCTs of 2700 K, 3000 K and 4000K, a CRI of >80 and efficacies of up to 78 lm/W depending upon drive current, join the existing 400, 700 and 1000 lm modules in March 2011. ■

Intematix Introduces ChromaLit™ Remote Phosphor Lighting Systems

ChromaLit™ leverages a phosphor composite precisely layered onto a substrate, separated from the blue LED energy source. The independent phosphor emits light when excited by blue light. Because the phosphor has been separated from the energy source and can now be made in any shape and any color, unidirectional light, hot spots, inconsistency and design limitations are no longer SSL challenges.



The main components of a ChromaLit™ system

Unprecedented Design Freedom:

The ChromaLit collection implements precision optics manufacturing and Intematix's cutting-edge phosphor technology to provide lighting manufacturers with the capability to create previously unimaginable lighting systems in any shape and any color. Completely customizable in geometry, color temperature, CRI and substrate material, ChromaLit products offer flexibility and creative opportunities never before seen in luminaires. Uniform, curvilinear and three-dimensional lighting designs are now made possible where challenges existed with conventional LED approaches.

Brilliant Light Quality:

Design with ChromaLit to harness a glare-free, diffuse light source and create consistent, high-quality light across multiple fixtures. Unique patterns enhance color rendering, and Intematix's proprietary technology enables stable phosphor performance over the module's lifetime and color-consistent, uniform luminaires.

Process Problems Solved:

The interchangeability of ChromaLit simplifies binning management and reduces inventory of luminaires of wide spectral range. ChromaLit systems easily achieve multiple color specifications without replacing the entire luminaire. One standardized LED energy source can power multiple CCT, CRI and R9 requirements by simply replacing the ChromaLit, so one blue LED energy supply can be stocked alongside compact and easily swappable ChromaLit. As blue LEDs continue to improve in efficacy, the same ChromaLit can be easily integrated into new systems.

Unparalleled Lifetime Efficacy:

ChromaLit offers up to 30 percent higher system efficacy than conventional LED lighting systems by operating at a lower temperature, maximizing photon extraction and removing the diffuser. By relocating the light production



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process away from the energy source, the ChromaLit architecture produces significantly more light per input power, increases LED package lifetime and reduces LED chip junction temperature. ChromaLit system designs can take advantage of fewer LEDs, smaller heat sinks, higher LED drive currents and reduced energy usage.

Future Possibilities:

Our labs are continually developing new materials and improved processes. In the future, these advances will bring:

- Improved optical control
- Extended CCT and CRI options
- Diverse environmental viability
- Specified shapes and sizes ■

Tyco Electronics Introduces the All New NEVALO SSL System

Solid State Lighting is expected to grow to more than half of all residential and commercial fixtures in the next few years. Tackling new designs and converting your existing luminaires and fixtures to SSL requires new technology and new expertise. The NEVALO SSL System is designed to facilitate the transition from traditional light sources to new electronic LED lighting fixtures.

The new NEVALO SSL System from Tyco Electronics is designed to move luminaire manufacturers into this new world quickly, efficiently and reliably. This highly-engineered state-of-the-art, plug-and-play system relieves you of the electronic and thermal engineering tasks so you can focus your resources on what you do best.

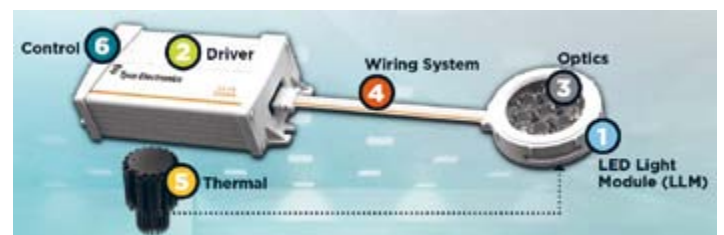
The NEVALO SSL system covers all components necessary to build a luminaire, from LED modules over optics, drivers, thermal management systems and wiring systems, and it is compatible with most standard dimmers.

Instead of a lamp socket (and possibly a ballast), the SSL fixture can include power conversion and control electronics, the light

The NEVALO Solid State Lighting Design Orbit consists of all necessary components for building SSL fixtures



NEVALO SSL System modules are designed as building blocks



source and optics, interconnections and heat dissipation. The NEVALO Solid State Lighting System from Tyco Electronics combines all of these functions into an integrated, plug-and-play solution. This Design Orbit describes each of the essential elements.

The NEVALO SSL System components are designed to meet both requirements. LED Light Modules (LLM) are offered in rectangular and circular configurations with multiple LED configurations. Drivers, cables, and connectors are designed with flexibility in mind. Heat sinks are offered to match every LLM. For circular systems, sockets and optics complete the job.

The SSL system budget simplifies fixture design and decreases opportunities for errors. Color coding confirms that the right sub-assemblies have been chosen. As you build your system, you simply check that the color codes match and that the total LLM budget is within the specific driver's range.

The NEVALO configurator allows easy incorporation of innovative lighting components into a customized system. Backed by Tyco Electronics' engineering expertise and available five-year warranty, the NEVALO configurator helps users to create efficient solutions, build a bill of materials and submit a project for a quote.

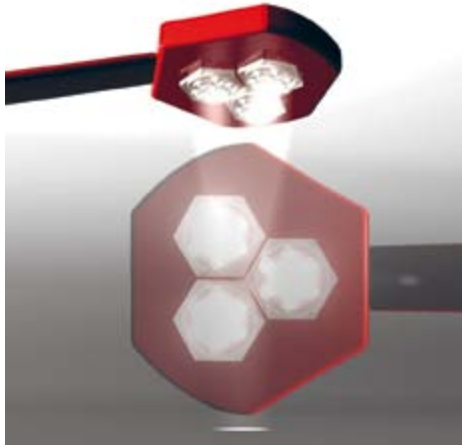
With "Thermal Monitor", an evaluation tool is provided to confirm the thermal performance of every LLM in your fixture design. The evaluation tool includes PC software plus a thermal test board that matches the production version of the LLM.

SSL designer kits are available by application type: downlight, wall mount and track, and additional NEVALO system components for various lumen outputs. Each kit includes drivers, LLMs, heat sinks, wiring systems and technical product information which assist in the creation and validation of a designer's luminaire design concept. ■

OptoDrive's Minor Surgery LED Engine offers 30 klx and Excellent R9 Values

The new Svea LED Engine is the latest design in the Optodrive concept with less radiated heat and less energy consumption than any incandescent alternatives. An LED based light source that reaches 30 klx from such a small size as 90 mm (3.5"), easily integrated in surgical light sources for high intensity illumination. Excellent possibilities to reach a

perfect shadow control with a multi array design and a crisp white light with excellent R9 values. Reduced heat output and a prolonged lifetime compared to conventional light sources.



The OptoDrive SVEA is a complete compact light module comprising lens, driver and LEDs

Technically, a light source designed for minor surgery, examination lights and other medical applications as well as for veterinarian use to meet the following directives: EN60601-2-41 IEC: 2000, UL60601-1 and CAN/CSA-C22.2 No. 601.1-M-90.

Specification:

The LED Engine is designed with an internal driver and is easy to connect in applications for 24-36 VDC or with external wall outlet transformer. The efficiencies are the highest available on the market for such applications. Lenses are integrated with a viewing angle of

9.5°. Light intensity 30,000 lx in one meter distance with D50/D10 requirement fulfilled. The hexagon design form makes it easy to combine in different shapes and solutions. It can therefore easily be adopted in satellite combination or other major surgery applications.

The new OptoDrive SVEA 24W-LED medical module 4300 K meets the demands for Australian hospitals and medical areas where all luminaires are required to comply with the Cyanosis Observation Index (COI) as per AS1680.2.5:1997.

Applications:

The LED engine is designed for light fittings and luminaires aiming for the minor surgery and medical area to meet the demands on high performance optical solutions in both light emitting and in color rendering. Mechanically it is constructed with our package design Svea (90 mm) that have the same footprint as all others in the family both for external drivers as well as built in driver for 110/230VAC.

Svea Package:

The same package is used for Down-, Spot-, Task- and Medical light fittings. The solution is developed to make it easy for the design engineers to mix between low to high power and from AC to DC in the same luminaires or in similar design. In the design concept there are standard dimmers with the same snap in connector (that fits the whole OptoDrive concept™) as well as several heat sink designs with worldwide distribution.

OptoDrive LED Modules:

Provide a superbly balanced light and excellent color reproduction. Many tasks demand extra accuracy in color perception, having achieved a Color Rendering Index value (CRI) which exceeds the standards of workplace lighting. OptoDrive LED modules provide the solution for many applications apart from Medical Lighting, such as, food retailing, art galleries, fashion/clothing displays. ■

Cree Uncovers Revolutionary LED Light Bulb

131 years ago, Thomas Alva Edison was granted U.S. patent 223,898 for "Improvement in Electric Lamps and in the method of manufacturing." Today's LED lighting revolution heralds the demise of Edison's horse-and-buggy-era invention.

In an industry first, Cree, Inc. has demonstrated the brightest, most-efficient, LED-based A-lamp that can meet ENERGY STAR® performance requirements for a 60-watt standard LED replacement bulb. This unprecedented level of performance is the result of Cree innovation, Cree barrier-breaking LED performance, Cree TrueWhite® Technology and patented Cree remote-phosphor technology.

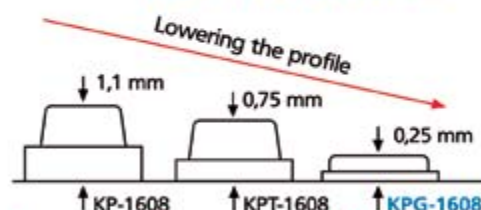
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Super-flat SMD-LED with height of just 0,25mm

KPG-1608 series



Quality — Efficiency — Innovation — First-class service



Cree, Inc. has demonstrated the brightest, most-efficient, LED-based A-lamp that can meet ENERGY STAR® performance requirements for a 60-watt standard LED replacement bulb

Samples are available in March and production volumes are available with standard lead-times from April onwards. ■

A Long-Lasting LED to Replace A19 Incandescent Bulbs

GlacialLight, a sub-division of the experienced technology manufacturer GlacialTech Inc., launches all-new Lyra Series of LED products with the GL-A19 LED bulb. Designed as a direct replacement for traditional A19 incandescent bulbs, GlacialLight's A19 LED fits into standard E26/E27/B22/GU10 sockets. With GlacialLight's two-year warranty and a rated life-span of at least 30,000 hours, the LED bulb is designed to provide exceptional and long-lasting decorative, window, spot, cabinet, accent, and hallway lighting, in both commercial and private settings.

"This is a significant milestone for the industry," said Chuck Swoboda, Cree chairman and chief executive officer. "In the race to commercialize low-cost, energy-efficient LED bulbs, the industry has forgotten that LED lighting is supposed to look as good as the technology it is replacing. This is the first no-compromise replacement for a 60-watt incandescent bulb."

The prototype bulb is dimmable and emits a beautiful, warm, incandescent-like color of 2700 K, with a CRI of at least 90. It delivers more than 800 lumens and consumes fewer than 10 watts and has been submitted for third-party testing to validate the light distribution, lumen maintenance and performance.

"We are committed to leading the market and showing the industry what's possible with recent innovations in our LED products and technology," said Swoboda. "We are excited to show the world what it should expect in an LED light bulb and enable our customers' products with these innovations."

No commercially available LED A-lamps meet the ENERGY STAR® performance requirements for 60-watt standard replacement bulbs at this level of efficiency and light quality. ■

Ledzworld Launches MR16 – 6.5 W Cree MT-G with 450 lm

Ledzworld Technology, an innovative R&D and manufacturing company, launches its new LED retrofit MR16, a low power-consumption 6.5 W LED lamp that produces an industry – leading high output of 450 lm. The lamp has an efficacy of >70 Lumen/W at a color temperature of 3000 K.

Just two days after Cree made its first official media announcement of a new lighting class LED designed for high-output small form factor directional lighting, Ledzworld launches the first lamp that integrates the latest Cree multi-die MT-G LED with its own superior thermal design and driver- technology.



GlacialLight's all-new Lyra Series of LED products with the GL-A19 LED bulb fits into standard E26/E27/B22/GU10 sockets

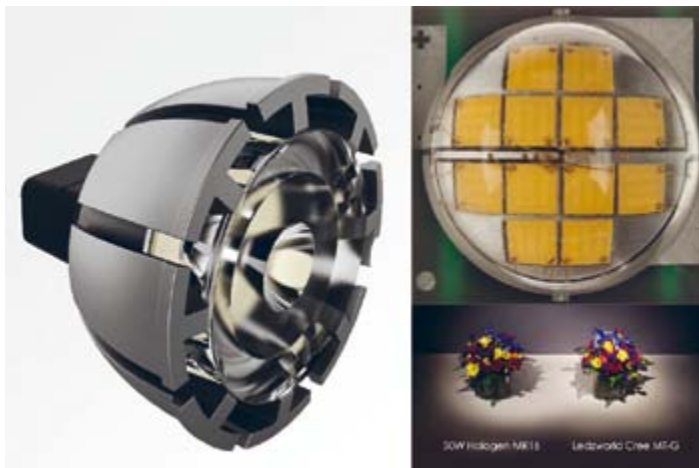
Specifications:

Power Consumption: 9 W
Input Voltage: 100-240 V±10%AC
Luminous Flux: 640 lm(CW) / 500 lm(WW)
Luminous Efficacy: 71 lm/W(CW) / 56 lm/W(WW)
Operating Temp. Range: -20°C to +40°C
CCT: 3000 K(WW) / 6000 K(CW)
CRI: > 80(WW) / > 70(CW)
Beam Angle: 120°
Warranty: 2 years

LED Lyra Series Features:

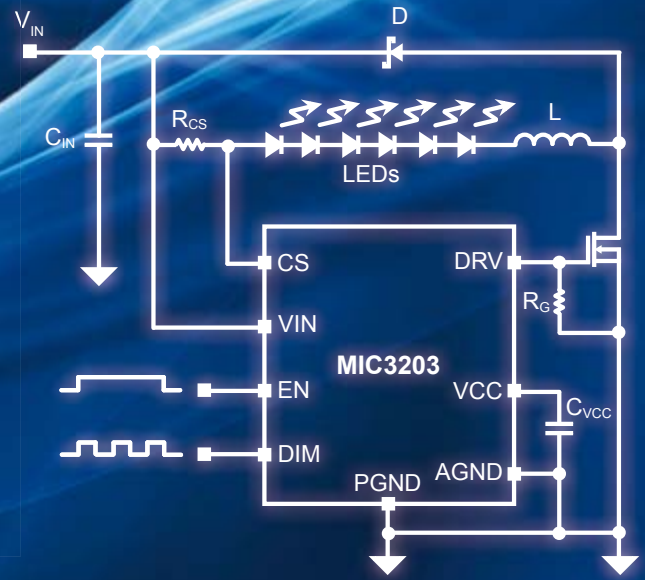
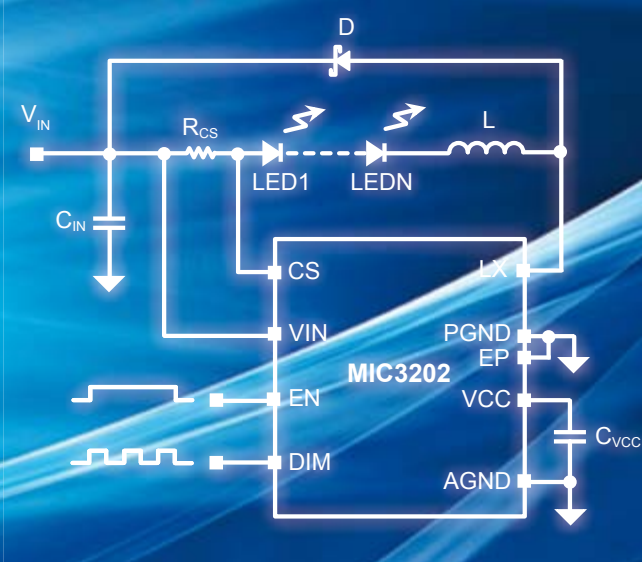
- Direct replacement for any A19 incandescent bulb
- Low power consumption – energy-saving
- Power conversion efficiency > 83%
- Power factor > 0.8 at 120VAC / > 0.75 at 240VAC
- Long lifetime > 30,000 hrs
- Eco-friendly: RoHS Compliant
- No UV, no IR, & no mercury

Ledzworld launches new MR16 lamp with Cree's Xlamp MT-G, just 2 days after Cree announced its brand new MT-G LED and accomplishing reference design



Bringing the Power to Light™ with Simple HBLED Drivers

High Brightness LED Drivers with High-Side Current Sense



Applications



The rapid growth of LED lighting applications in commercial, industrial and automotive markets has led to a wide variety of technical challenges for LED Drivers. Micrel is meeting these challenges with simple step-down LED Drivers such as the MIC3202 and MIC3203.

The MIC3202 is a hysteristic step-down LED Driver with integrated MOSFET capable of driving up to 10 HBLEDs with constant currents up to 1A in a thermally enhanced exposed pad SOIC-8L package.

The MIC3203 is a hysteristic step-down LED Driver with an external MOSFET capable of driving up to 10 HBLEDs with power levels up to 40W in a SOIC-8L package.

For more information, contact your local Micrel sales representative or visit Micrel at: www.micrel.com/ad/leddrivers.

Ideal for use in:

- ◆ 12V Lighting Systems (MR-16 Bulb, Under Cabinet Lighting, Garden/Pathway Lighting)
- ◆ Architectural, Industrial, and Ambient Lighting
- ◆ LED Bulbs
- ◆ Indicators and Emergency Lighting
- ◆ Street Lighting
- ◆ Channel Letters

Part Number	Input Voltage	Output Current	PWM Dimming	Dithering	Package
MIC3202	6V to 37V	1A	Yes	Yes	EP SOIC-8L
MIC3202-1	6V to 37V	1A	Yes	No	EP SOIC-8L
MIC3203	4.5V to 42V	Controller	Yes	Yes	SOIC-8L
MIC3203-1	4.5V to 42V	Controller	Yes	No	SOIC-8L

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or indoor use, the GL-A19 LED bulb takes an AC 100-240 V power source, uses less than 9 watts of power and emits over four hundred lumens of "Warm White" or "Cool White" light. Properly surrounded by heatsink fins to cool down, this energy-efficient GL-A19 LED bulb by no means scalds its users even when in use. With significantly lower levels of heat-generation, as compared with incandescent bulbs, the A19 LED bulb also benefits its users with power/ money savings due to lowering air-conditioning bills.

GlacialLight designed the GL-A19 LED Lyra Series bulb to contain no hazardous chemicals, such as mercury, or emit no harmful UV rays, making it more eco-friendly than traditional incandescent lighting fixtures. With a power conversion efficiency of greater than 83%, GlacialLight is extremely excited to give consumers the LED Lyra Series – an economically and environmentally-friendly line of lighting products. ■

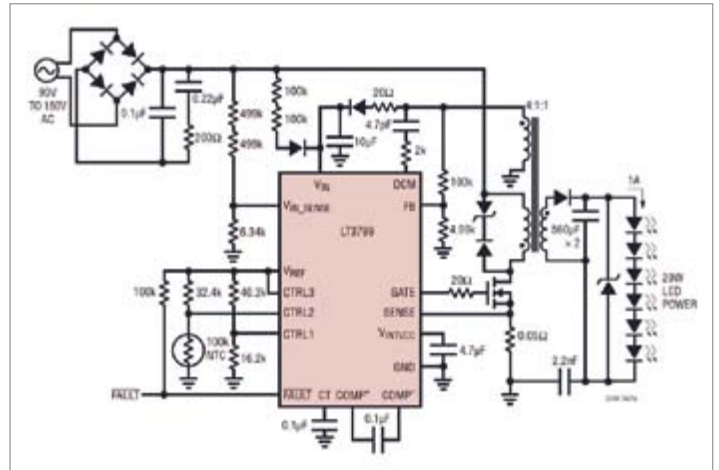
LED IC for TRIAC Dimmable Isolated Active PFC Off-Line Driver without Opto-Coupler

Linear Technology announces the LT3799, an isolated LED controller with active PFC, specifically designed for driving LEDs from a universal input range of 90 VAC to 265 VAC. The LT3799 is optimized for LED applications requiring 4 W to over 100 W of LED power and also compatible with standard TRIAC in-wall dimmers. The controller's unique current sensing scheme delivers a well regulated current to the secondary side without using an opto-coupler.

Features:

- Isolated PFC LED Driver with Minimum Number of External Components
- TRIAC Dimmable
- VIN and VOUT Limited Only by External Components
- Active Power Factor Correction (Typical PF > 0.97)
- Low Harmonic Content
- No Opto-Coupler Required
- Accurate Regulated LED Current ($\pm 5\%$ Typical)
- Open LED and Shorted LED Protection
- Thermally Enhanced 16-lead MSOP

Typical application circuit for a Triac dimmable application with the LT3799 offers current control without opto-coupler



Package

Applications:

- Offline 4W to 100W+ LED Applications
- High DC VIN LED Applications

This not only reduces cost but also improves reliability. Its single stage PFC regulator design requires minimal external components. Additionally, it's thermally enhanced MSOP-16E package ensures a simple and compact solution footprint for off-line LED applications.

The LT3799 offers over 86% efficiency, eliminating the need for external heat sinking of the LED driver IC in most applications. Special internal circuitry provides active PFC of up to 0.97, easily meeting industrial Department of Energy (DOE) requirements while also complying with the IEC 61000-3-2 Class C Lighting Equipment Harmonics requirement.

The LT3799 can be used with a standard in-wall TRIAC dimmer without any visible flicker. Open and shorted LED protection ensures long-term reliability for a wide range of LED applications. ■

High Power-Factor-Corrected Digital LED Driver IC Delivers Flicker-Free Dimming

iWatt, Inc., a developer of energy-efficient digital power supply control integrated circuits (ICs) used in leading-edge power supplies, expanded its family of digital LED driver ICs with a two-stage, power-factor-corrected (PFC), primary-side-regulated, leading- and

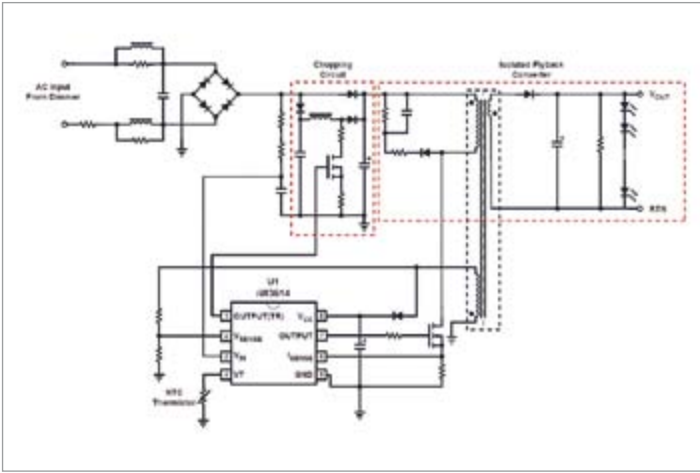
trailing-edge-dimmable, AC/DC Digital PWM Controller targeting 120V/230 VAC offline commercial and industrial LED lighting applications. Designed for isolated or non-isolated LED drivers used in incandescent replacement lamps, the iW3614 (3 W to 15 W) incorporates features to assure power efficiency, durability, reduced size and component costs, and flicker-free compatibility with existing wall dimmers worldwide.

The iW3614 is targeted for commercial and industrial LED lighting applications. iW3614 includes hot-plug support, where the user can swap the LED engine without recycling the input power for the LED driver.

The iW3614 features a two-stage PFC scheme on a single chip. A front-stage boost converter enables PF > 0.90 (typically 0.94), while the following PWM driver stage minimizes ripple current at the output. This scheme eliminates the disadvantages of a single-stage design, such as the low 100 Hz/ 120 Hz line frequency ripple and resulting flicker at the output. Reducing the output ripple current also enables smaller output capacitors, leading to size, cost and reliability benefits.

A single-stage PFC design can also limit the dimming range (typically 10% to 100%) as it may lack a bulk electrolytic storage capacitor to store energy and subsequently power the LEDs when the dimmer phase cut is low. iWatt's two-stage design overcomes this challenge with a small bulk storage capacitor to allow a wide (1% to 100%) dimming range.

In iWatt's LED driver ICs, intelligent digital algorithms automatically detect all types of dimmers or a lack thereof, for flicker-free operation with existing wall dimmers



Typical application circuit for a flicker free LED driver using iWatt's iW3614 driver IC

worldwide, including both leading-edge (TRIAC style) and trailing-edge dimmers. In case of an unsupported dimmer, safe mode shuts it down. The device allows smooth, flicker-free dimming with tight $\pm 5\%$ LED current regulation.

iWatt's AC/DC power conversion ICs are unique in that they feature a digital feedback and control loop versus analog. This adaptive digital control technology optimizes efficiency and reliability, and simplifies printed circuit board (PCB) design. Precision primary-side-control technology to eliminate the opto-coupler and secondary-side control circuit, built-in frequency jitter and quasi-resonant (or valley-mode) switching to reduce EMI (over 6 dB margin and over 85% efficiency), and a high switching frequency up to 200 kHz combine to enable designers to reduce thermal loss, component count, driver size and bill of materials (BOM). Eliminating the opto-coupler, combined with low inrush and low ripple current by design can also lengthen the life of the LED driver assembly.

Comprehensive safety features include: LED open/short circuit protection, input over-voltage protection, and over-temperature thermal shutdown. An LED current de-rating at high temperatures also protects LEDs. The IC enables system designers to exceed all safety, EMI and regulatory standards, including the EN55015B, IEC61000-3-2 and Energy Star.

The chip comes in a low-cost, thermally-enhanced SO-8 package with an exposed pad which allows lower die junction-to-PCB thermal resistance for increased reliability. Samples are available, and the iW3614 is priced at \$1.13 in 1,000-piece quantities. ■

STMicroelectronics Raises Reliability and Efficiency for Ultra-Compact LED Lamps

The first in a new family of mains-operated LED lamp drivers from STMicroelectronics (NYSE: STM), the worldwide leader in ICs for electronic lighting control, will enable designers to deliver more reliable and efficient LED retrofit lamps featuring primary-side current regulation.

Major features of HVLED805:

- 800 V avalanche-rated MOSFET power switch
- 5%-accurate constant-current regulation
- Quasi-resonant operation
- High-voltage startup circuitry
- Open- or short-circuit LED string management
- Automatic self supply
- Input voltage feed-forward for mains-independent constant-current regulation

STMicroelectronics' primary-side regulation IC combines improved high-voltage integration and ultra-efficient operation for extremely accurate LED-lighting control



LED lighting, including retrofit bulbs, is expected to account for 80% of the lighting market by 2020 or sooner. Primary-Side Regulation (PSR) cuts bill-of-materials costs for retrofit bulbs, thereby reducing the payback time, while also simplifying design and reducing the space occupied by LED control circuitry.

The new HVLED805 integrates an 800 V avalanche-rugged MOSFET, achieved using ST's high-voltage integration process, which is higher than in competing devices and hence offers greater reliability. The high-voltage on-chip startup circuitry allows the device to start reliably when the AC line voltage is applied to the lamp.

Further technical information:

Primary-side regulation maintains the constant LED current that is needed to ensure consistent light output, without requiring the current-sensing components and opto-coupler used in conventional secondary-side regulation. The elimination of these components decreases the cost and size of the LED driving circuitry and saves current-sensing losses, improving overall efficiency.

Using PSR, the HVLED805 guarantees LED current regulation within 5% accuracy. Reliability is also enhanced, due to the elimination of the opto-coupler in the secondary side, whose degradation can significantly decrease the mean-time-between-failure of the lamp.

The robust 800 V power MOSFET allows a reduction of the snubber network. The highly efficient quasi-resonant (QR) operating mode further boosts energy savings for LED lighting and dramatically reduces the EMI filtering required, saving space and costs. ■

Maxim's LED Driver for Halogen MR16 Drop-in Replacements

Maxim Integrated Products introduces the MAX16840, an LED driver that employs a proprietary architecture to ensure flicker-free, dimmable operation with electronic transformers and cut-angle dimmers. Maxim's patent-pending approach enables the design of retrofit LED lamps that can replace halogen MR16s without any changes to the existing electrical infrastructure. This removes an important obstacle to commercial viability, allowing end users to enjoy all the benefits of LED lighting with substantially lower deployment costs.

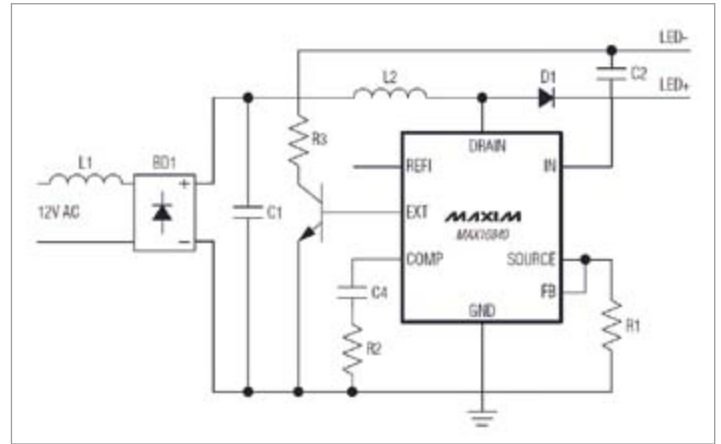
Features:

- Control of the average input current to achieve operation with electronic transformers and dimmability
- Buck, boost, SEPIC, and buck-boost
- Integrated 0.2 Ohm (max) 48 V switching MOSFET
- Analog dimming and thermal fold back
- External npn driver to guarantee minimum load to electronic transformer at startup
- Output overvoltage protection
- Internal over temperature protection
- -40°C to +125°C operating temperature range
- 3x3 mm, 10-Pin TDFN package

To facilitate adoption, LED retrofit lamps must be compatible with electronic transformers and cut-angle dimmers. These transformers and dimmers are designed for the perfectly resistive loads of traditional halogen lamps. LED drivers, however, are very nonlinear and not purely resistive loads. As a consequence, LED lamps flicker, do not dim, and in some cases do not turn on at all when used with the existing electrical infrastructure.

The MAX16840 solves this problem by using a unique, patent-pending approach to control the input current of the lamp. By actively shaping the input current it ensures flicker-free operation with most electronic transformers and dimmers. This enables LED lamp designers to create drop-in replacements for halogen MR16s, thus eliminating the costly infrastructural upgrades required by competitive solutions.

Typical application circuit with MAX16840



In addition, the MAX16840 can be designed in without electrolytic capacitors. This extends the lifetime of the LED lamp, since electrolytic capacitors are usually the first component that fails in the driver circuit, and reduces the cost and size of the driver, allowing it to fit in the small MR16 form factor. An integrated switching MOSFET further extends these space savings while reducing component count and cost.

The MAX16840 can deliver up to 20 W of power in a thermally enhanced, 3x3 mm, 10-pin TDFN package. Prices start at \$2.01 (1000-up, FOB USA). ■

Innovative LED Driver by dilitronics makes Light usable as a Design Medium

dilitronics GmbH presents an innovative driver for controlling LEDs. The MCC16 with ground-breaking characteristics has been specially developed for interior applications. The compact design in combination with DMX, TCP/IP or DALI interfaces and a capability of separately controlling up to 16 LED modules is revolutionary, and opens up completely new concepts for the use of LEDs in interior lighting. Whether workplace lighting, accent lighting for hotels and bars, or flexible area lighting for conference and seminar rooms, demanding individual lighting concepts based on LEDs are now feasible.

Not only since the 2009 ban on conventional light bulbs have LEDs increased in importance for interior lighting. Their light characteristics and the ability to control them individually

make them a better alternative. As Meinrad Braun, Sales Director at dilitronics, explains: "What was missing up to now was an efficient driver that reduces the still high installation costs, to make LED lighting more economical and thus to open up new applications. With the MCC16 we are presenting a driver that significantly reduces the number of components required and that sets new standards in terms of efficiency."



The dilitronics MCC16DMX allows controlling of various LED luminaires easily

At the heart of the MCC16 is the innovative DIL16CL01 LED driver. This LED chip, developed by dilitronics, enables a space-saving design and direct access to each individual LED channel via the integrated communications interface. As Braun explains: "The main feature of the MCC16 is a TCP/IP interface. The use of TCP/IP in lighting technology is not entirely new, but only a few lighting technology products have been developed up to now on the basis of this protocol. Its advantages, however, are obvious: The transfer of large amounts of information thanks to the extremely high bandwidth, and the control of large numbers of light sources thanks to the almost unlimited address range." Using TCP/IP in combination with a 16-channel high-power LED driver is an enormous evolutionary step in lighting technology.

The Art Inside Intelligent Lighting

If your visions are to become reality you need both creativity and technical expertise. With us you are the artist – creating light, connecting light, controlling light. As a proven solutions provider to some of the world's leading lighting companies, as well as a pioneer in enabling green technologies, Renesas Electronics has what it takes to help you realise your visions in energy-efficient, safety certified and network-enabled intelligent lighting.



Unique

- **World's 1st microcontroller** with integrated constant current driver for large scale high brightness LED systems.
- **World's 1st microcontroller** providing LED drive and Power Factor Correction in a single chip.
- **Award-winning** high integration, dedicated function low cost fluorescent & HID ballast microcontrollers.

Easy

- Graphically create complex lighting sequences, colour mixes, fine-step dimming, flashing and strobing.
- Graphically configure and control integrated DALI and DMX512 networking functions.
- No previous experience needed with dedicated starter kits and software tools for white, colour and general lighting.

Complete

- 1st class support from the world's leading microcontroller supplier.
- Full development & reference platforms.
- Full software libraries.
- Full solution portfolio:
 - Power MOSFET's - IGBT's
 - Optocouplers - LED Drivers
 - PFC IC's - ZigBee™
 - Powerline ...

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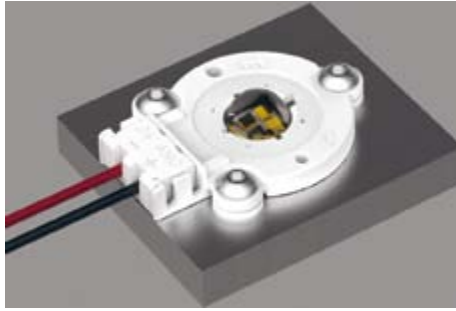
Application areas for the MCC16 are all lighting systems that use LEDs as the light source: Offices, shops and boutiques, public buildings, private homes and apartments, hotels, bars, restaurants, spa and wellness facilities, exhibitions, trade fairs, museums, stage lighting, entertainment lighting, media facades, media installations, cruise ships, yachts, industrial buildings, warehouses, leisure parks. In Braun's words: "Primarily wherever a large number of light sources have to be controllable and energy-efficient."

The innovative company presented the DIL16CL01 LED driver for the first time at the "Light and Building 2010" trade fair. Smaller than a 2 cent coin, the chip can boast an ability to control 16 high-power LEDs or LED modules in parallel, and with extremely high power levels per channel. "The MCC16 is the logical next step of the DIL16CL01 for exploiting the advantages of the controLED technology for lighting applications". To quote Braun on further development projects: "The MCC16 product range will be further expanded to further simplify the installation and operation of LED lighting." ■

Tyco Electronics Launches Solderless LED Socket for Philips Lumileds Luxeon™ S LEDs

Tyco Electronics (TE), a global leader in engineered electronic components and solutions, launches the solderless LED socket, Type LS, designed specifically for use with the new Philips Lumileds LUXEON™ S LED. Debuting at Strategies In Light 2011 in Santa Clara, California, the new product offers a solderless termination that complements this newly-released lighting-class LED by Philips Lumileds.

The Type LS socket complies with UL-1977 specifications and is designed with insulation displacement technology to allow for quick and easy termination of 24 AWG wires to the socket. An integral stainless steel spring within the socket ensures that uniform and adequate normal force is applied to the LED for optimum thermal performance.



Tyco Electronics expands its solderless LED socket product range with a version for Philips Lumileds Luxeon™ S LEDs

Additionally, the product simplifies the positioning of the Luxeon S LED on a heat sink by utilizing a locator -- a plastic frame that is first placed on the heat sink to correctly orient the LED in its position prior to socket attachment. Once positioned, only three commercially-available #4 or M3 screws are needed to rapidly secure the socket to the heat sink.

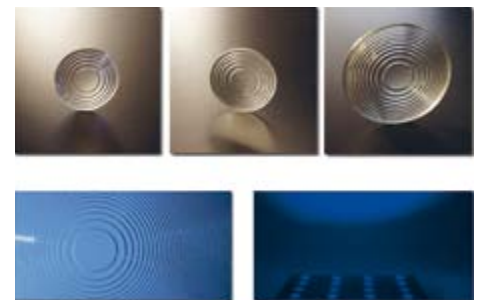
Designed to maximize optical efficiency in un-lensed applications, the shape of the Type LS socket ensures that 98 percent of the light emitted from the LED is unobstructed. Offered both with and without optics snap features, it provides flexibility for fixture designers by providing features for a secondary optic attachment. For optical flexibility, the matching Venla series of reflectors are offered by LEDIL OY in a wide variety of beam angles and offer a simple snap-fit to the socket.

Customer drawings, 3D-model files and application specifications are available on this site. Production will begin in late March 2011. Additional information can be obtained by contacting the TE Product Information Center at 800-522-6752.

The TE Type LS socket, LUXEON® S LED, LEDIL reflectors and associated driver solutions will also be stocked and available through Future Lighting Solutions (www.futurelightingsolutions.com), a leading provider of LED lighting solutions. ■

LUXeXcel's "Printoptical Technology" for fast Development of LED Lighting

LUXeXcel has successfully developed and patented a digital printing process to generate three-dimensional optics which can be used to manufacture lenses and light distribution structures. This innovative production process immediately provides the LED lighting industry with all-new opportunities for growth.



LUXeXcel offers revolutionary 'Printoptical Technology' for accelerated optics development for LED lighting

New energy-saving LED fixtures can be brought onto the market faster, cheaper and with greater flexibility. What's more, this digital printing technology also opens up new product design possibilities for (O)LED lighting manufactures.

Richard van de Vrie, CEO of the LUXeXcel Group: "I'm thrilled that our team has succeeded in making this ground-breaking digital technology applicable for development of LED lighting optics. Printoptical Technology will also become a basic technology for many other target markets."

"Expensive tools and long development times for optics are definitely a thing of the past, and manufacturers will no longer need to keep large stocks of different lenses on hand because they can be printed out with the click of a button. 'Printoptical Technology' can even save on shipping costs because optics can be sent digitally to a printer anywhere in the world," adds Kurt Blessing, CTO van LUXeXcel.

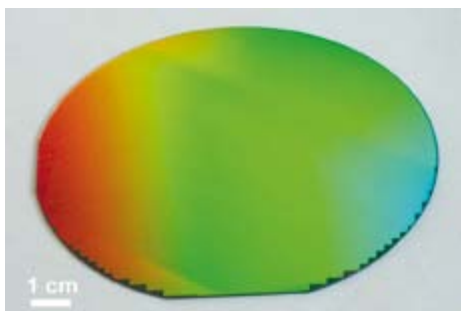
It is a matter of graphic design to insert logos, technical data or design elements into the same production process. Optical structures and elements can be printed on

non-traditional materials as well. Furthermore, optical adjustments are quite simple to perform in case, for instance, bifocal or trifocal optics are needed, or quick product changes are requested.

Paul Kallmes, CIPO of LUXeXcel and Managing Director of LUXeXcel Technologies Inc. (Silicon Valley, California), also sees major possibilities for the advanced North American LED lighting market. LUXeXcel's Printoptical Technology significantly reduces the 'time-to-market' – where lens development is usually the bottleneck. In addition to this, we are also making a lasting contribution to the 'energy saving' LED revolution. ■

Major Milestone Passed with Photonic Crystal Patterning on Full 4" Wafers

Eulitha AG of Switzerland and Dai Nippon Printing Co., Ltd. (DNP) of Japan announced the successful patterning of 4" wafers with Eulitha's proprietary PHABLE technology. Photonic crystal patterns with 600 nm period and hexagonal symmetry was created uniformly over 4" wafers.



Photonic crystal pattern on a 4-inch wafer fabricated with PHABLE technology using a photomask made by DNP

PHABLE (also see [LED professional news from Oct 19, 2010](#)) is a novel mask based photolithography technology that promises to revolutionize production of photonic structures such as photonic crystals, diffraction gratings and anti-reflection surfaces. High-throughput fabrication of such patterns over large areas is required for fabrication of high performance future devices in fields including LEDs, solar cells and flat-screen displays. In PHABLE a mask is

illuminated with a UV beam to form a high resolution image that has a very large depth of focus. Therefore substrates with non flat surfaces can be patterned easily.

The necessary high-resolution mask with the same 4-inch area as the final pattern was produced by DNP on a standard quartz/Cr plate. UV photolithography exposures were performed on a PHABLE-R lithography tool made by Eulitha. Photonic crystal patterns consisting of circular holes on a 600-nm period hexagonal lattice were printed in a commercially available photoresist coated on Si wafers. The produced patterns were highly uniform over the whole 4" area of the wafers.

Demonstration of uniform patterning on 4" substrates is an important milestone as most targeted applications require patterning of large areas. For example, the high brightness LED industry is switching to 4" and 6" wafers from the traditional 2" base. Photonic crystal structures that enhance light extraction in LEDs or patterned sapphire substrates that improve performance of LEDs grown on them can be fabricated with the PHABLE technology. Similarly, the required substrates for nanowire based LED or solar cell applications can be produced with this technology.

Eulitha currently offers samples and wafer batch processing services to companies and researchers developing nanostructure-based products. It is also currently offering laboratory lithography tools for 2"-4" wafers that are suitable for product development. ■

New 12-Inch Sapphire Wafers for High Quality Lighting Industries

Rubicon Technology, Inc., a leading provider of sapphire substrates and products to the LED, RFIC, Semiconductor, and Optical industries, announced the production of 12-inch polished wafers, the largest high-quality, sapphire wafer ready for production of LEDs (light emitting diodes). Rubicon now offers a complete range of high quality sapphire substrates including two-, three- and four- inch core, and six-, eight- and 12-inch wafers.



Rubicon now offers a complete range of high quality sapphire substrates including two-, three- and four- inch core, and six-, eight- and 12-inch wafers

Rubicon is uniquely positioned to deliver the sapphire capacity necessary to support the growing demand for LEDs in the consumer electronics and general lighting industries in products such as light bulbs, large displays, traffic lights, HDTVs, tablets, netbooks, and mobile phones leverage LEDs. As the only vertically integrated manufacturer of high quality, large diameter sapphire wafers in large volumes, Rubicon is the provider of choice for manufacturers of LEDs worldwide.

"Rubicon has built a world renowned R&D and engineering team that is making great strides in the development of high quality large diameter sapphire including the first 12-inch wafer," said Raja Parvez, Rubicon President and CEO. "It takes unique technology with advanced processes to make high quality, large diameter sapphire at scale. Rubicon's ability to affordably produce larger wafers, free of defects is key to helping industries that make and use LEDs scale to the volumes necessary to support the growth needed in the general lighting and consumer electronics."

Founded 2000, Rubicon sought after experts in sapphire crystal formation and processing, and the optoelectronics and semiconductor industries from around the world to redefine the end-to-end process for the manufacture of sapphire wafers.

"The Rubicon team has built a highly specialized end-to-end process to ensure the high quality of our full range of wafer products," commented Parvez. "It is very important to ensure that our customers can depend on us for uniform, particulate-free sapphire wafers as well as flat, stress-free wafers. High quality sapphire wafers help our customers produce high quality LED wafers at volumes supporting the LED supply chain."

Rubicon's recent build-out of infrastructure optimizes the company's ability to make affordable, high quality, large diameter sapphire wafers in large volumes for customers worldwide. The new facility in Malaysia leverages the location to further lower costs and bring extensive experience in polishing large diameter wafers closer to the LED, consumer electronics and general lighting manufacturers in Asia. ■

Juki Debuts JX-200LED High Speed Placement System for LED Applications

Juki Corporation, a world-leading provider of automated assembly products and systems, introduces the JX-200LED for the LED assembly market.



Juki JX-200LED is designed especially for the LED assembly market

Targeted specifically for LED manufacturing, the JX-200LED features new algorithms created for the placement of side- and top-view LEDs, rectangular ferrite chip-type and PLCC-type LEDs, making it the ideal low-cost placement solution for LED chips.

The JX-200LED features a new upward looking camera for QFP/QFN lead inspection and BGA ball inspection, as well as 1200 mm board capability with multi-indexing. Additionally, the placement system was designed to be able to support a 31.5 x 14"

board size when indexed twice in the machine, and a 47.2" board when indexed three times.

The JX-200LED placement system uses the same state-of-the-art, high-resolution, optical vision centering placement technology found throughout the entire Juki product line. Components are rotated 360° in the laser. Additionally, the system supports an automatic tool changer, which enables a variety of nozzles to be automatically changed during manufacturing.

With speed in mind, the JX-200LED can place 15,300 chips per hour at IPC 9850 and supports the placement of parts from 1005 SMTs to 33.5 mm². The JX-100LED also features an optional tri-colored vision centering system that can be used for placing fine-pitch QFPs, BGAs and QFNs for added flexibility and accuracy.

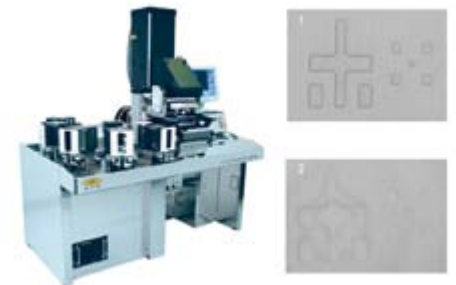
All Juki placement machines come standard with a three-year parts and one-year labor warranty. They also include no charge for attendance at any regularly scheduled training course at Juki facilities, free machine software upgrades for life of machine, free 24-hour phone support and are supported by a world-class service organization. ■

EV Group Expands Portfolio of Products: EVG620HBL Mask Alignment System

EV Group (EVG), a leading supplier of wafer-bonding and lithography equipment for the advanced semiconductor and packaging, MEMS, silicon-on-insulator (SOI) and emerging nanotechnology markets, announced the latest addition to its portfolio of products created to optimize the manufacture of high-brightness light-emitting diodes (HB-LEDs), compound semiconductors and power electronics. The new EVG620HBL fully automated mask alignment system builds on EVG's field-proven mask aligner platform, adding a high-intensity ultraviolet (UV) light source and five cassette stations – significantly more than competitive offerings – to enable continuous fabrication of devices. As a result, the EVG620HBL delivers unparalleled throughput of up to 165 six-inch wafers per hour (up to

220 wafers per hour in first print mode) with the industry's highest alignment accuracy and yield.

As with its dedicated EVG560HBL automated wafer-bonding system, introduced last July, EVG developed the EVG620HBL aligner to address these needs. EVG is not new to this market – its bonders and mask aligners are being deployed by four of the top five major HB-LED manufacturers. Building on this success, the company created the 620HBL in response to customer demand for a mask alignment system dedicated to meeting these devices' yield and throughput requirements.



EVG620HBL (left) and Microscope pictures (left) of alignment marks on a sapphire-based HB-LED wafer with standard optical setup (2) and the EVG620HBL (1).

Another key feature of the EVG620HBL is the availability of special recipe-controlled microscopes whose illumination spectrum is optimized to ensure the best pattern contrast with various wafer and layer materials, including such advanced substrate materials as sapphire, silicon carbide (SiC), aluminum nitride (AlN), metal and ceramic.

"Our ongoing R&D efforts and focus on innovation in equipment manufacturing and process engineering are enabling EVG to consistently deliver the state-of-the-art, high-volume manufacturing solutions that our customers expect," stated Paul Lindner, EV Group's executive technology director. "Just last month, one of the leading HB-LED manufacturers ordered an EVG560HBL bonder, and the EVG620HBL is the latest result of our ongoing efforts around enabling HB-LED manufacturers to develop more efficient, cost-effective and higher yielding devices to meet their customers' demands. We look forward to making further inroads with this latest offering, which also features high-accuracy handling and alignment of fragile or warped wafers." ■

Labsphere Introduces New LED Measurement Systems

Labsphere announces its new XSLMS series light measurement systems which features extended dynamic range for different wavelength ranges and a broad variety of interchangeable light measurement accessories. NIST traceable total spectral flux standards enable simple in-house system recalibration and verification of the system. Spheres with diameters from 10 inch to 3 m with a nearly perfect Lambertian reflection of 98% are available.



A broad range of spheres, from 10 inch to 3m, is available for the XSLMS series system

Main Features:

Wide dynamic range allows a single sphere to measure a wide range of light levels
 NIST traceable standards for in-house recalibration
 Spectral results in milliseconds
 Comprehensive light measurement software

- Total spectral flux
- Luminous flux
- Radiant flux
- Chromaticity
- CCT
- CRI
- Peak wavelength
- Dominant wavelength
- I,V and luminous efficiency

Spectrafect® interior sphere coating
 IESNA recommended geometries

The XSLMS series systems combine intuitive software with high-speed hardware to simplify complex measurements. The coupling of application specific software with our CDS-9800 Series CCD-based spectrometers, integrating sphere, and cosine receiver makes it possible to deliver total spectral flux, luminous flux, radiometric flux, and colorimetric results in milliseconds.

The XSLMS-SPEC software guides users through testing, providing straight-forward testing procedures and repeatable results to meet the needs of both new users and experienced researchers. ■

Tower Automatic Storage System Increases the Flexibility of Production

The Tower automatic storage system from Essemtec simplifies logistics and increases the flexibility of the production. Component reels and trays can now be stored locally in production.



One tower offers storage space for 546 reels and can reduce component storage and management costs

For several months Variosystems has been testing the Tower storage system in production. Opened component reels and trays were not returned to the main storage any more but kept within the Tower. With this concept, logistic effort could be minimized, feeder setup time could be reduced and the production flexibility could be increased. Based on the positive experience and savings, the decision was made to automate the complete component stock and move it into production.

Variosystems implements multiple Tower automatic storage systems from Essemtec. The Tower protects components from ESD, humidity and high temperatures while they are not set-up on feeders. It features a controlled dry climate wherein components with MSL classification can be stored even without dry packs. Storage and retrieving of components is simple, fast and fully automatic.

A tower offers storage space for 546 reels. For more storage capacity multiple towers can be clustered. The system includes software for stock management and consumption tracking. Retrieving of components is just-in-time when they are needed for feeder setup. The access time for every component is only 8 to 12 seconds.

The Tower can reduce component storage and management costs in small or large production. It shortens access and handling time, avoids unnecessary baking of MSL classified components and it can save masses of MSL and ESD protection packing materials. ■

KLA-Tencor Launches New Inspection and Analysis Systems

TKLA-Tencor Corporation, the world's leading supplier of process control and yield management solutions for the semiconductor and related industries, introduced its new Candela® 8620 substrate and epitaxy (epi) wafer inspection system. In addition, KLA-Tencor introduces a broad portfolio of process control solutions designed to improve productivity of LED device fabs. KLARITY LED offers automated defect analysis for LED yield enhancement and rapid time to results, while ICOS WI-2220 provides low cost of ownership to support LED industry cost per lumen goals.

"The industry's current consensus estimates state that by 2013 the LED market will be growing at a compound annual growth rate of 25% or higher," said Jeff Donnelly, group vice president, Growth and Emerging Markets at KLA-Tencor. "Today's LED device makers are challenged with increasing performance at a lower cost, while supporting the industry's aggressive growth rate. With proven reliability and ease-of-use, KLA-Tencor's comprehensive portfolio of LED defect inspection and analysis solutions is designed to enable tighter process control and overall yield improvements for LED production at decreased cost per lumen."



ILD 4035 and ILD 4001 Step-down LED drivers for 1W and 3W+ LEDs



The new ILD 4035 and ILD 4001 from Infineon Technologies are part of a new LED driver family dedicated to general lighting applications.

- 40V input voltage
- 350mA LED current (ILD 4035)
- Up to 5A LED current with external MOSFET (ILD 4001)
- Overvoltage, overcurrent and thermal protection
- Small SC-74 package

To learn more about the LED driver portfolio for General Lighting, please visit www.infineon.com/lowcostleddrivers

CANDELA® 8620 INSPECTION SYSTEM FOR HIGH BRIGHTNESS LED MANUFACTURING:

Designed for high brightness light emitting diode (HBLED) manufacturers, the Candela 8620 provides automated defect inspection for LED materials such as gallium nitride, sapphire, and silicon carbide—enabling enhanced quality control of both opaque and transparent substrates, faster time-to-root cause, and improved Metal Organic Chemical Vapor Deposition (MOCVD) reactor uptime and yield.

KLARITY LED: DEFECT ANALYSIS AND DATA MANAGEMENT SYSTEM FOR LED YIELD ENHANCEMENT

Based on the industry-leading KLARITY Defect product for integrated circuit manufacturing, the new KLARITY LED provides a high performance solution for LED device makers, including automated in-line scan analysis for the entire fabwide manufacturing process. The LED industry is evolving from traditional tool-centric manual defect checks, with automated optical inspection only at the end-of-line stage, towards adopting sophisticated fabwide process control and defect analysis with in-line inspection. As a result of front-end to backend connectivity, KLARITY LED delivers faster excursion detection and root-cause analysis than prevailing industry methods to enable effective decision making, thus helping reduce the impact of materials risk and improve yields. With KLARITY LED, KLA-Tencor introduces to LED device makers an advanced in-line alternative solution for automated defect analysis of LED production processes, and an option to more efficiently share performance and reliability data within their organization for faster yield learning, while replacing existing labor-intensive manual report generation methods.

ICOS WI-2220: SCALABLE DEFECT INSPECTION AND IMPROVED COST OF OWNERSHIP IN LED PROCESS CONTROL

The ICOS WI-2220's automated optical inspection capabilities help LED device makers realize increased yields and reduced production costs. With the ICOS WI-2220, device makers can automate inspection of smaller die sizes that inhibit manual inspection, and for larger die sizes that require rapid corrective action to limit costly

materials risk. The new system allows defect inspection of whole and diced wafers up to 200mm, with macro inspection sensitivity in the pre- and post-dice inspection (i.e. front- and back-end) of LED wafers. ■

Veeco Introduces MaxBright MOCVD Multi-Reactor System

Veeco Instruments Inc. announced today the introduction of the TurboDisc(R) MaxBright(TM) Gallium Nitride (GaN) Metal Organic Chemical Vapor Deposition (MOCVD) Multi-Reactor System for production of high-brightness light-emitting diodes (HB LEDs). MaxBright has already been accepted by a leading LED manufacturer and Veeco is currently shipping MaxBright systems to additional top manufacturers in Korea, Taiwan and China.



Veeco's TurboDisc MaxBright GaN MOCVD multi-reactor system offers industry-leading wafer capacity for wafer sizes from 2" to 8"

MaxBright leverages Veeco's market-leading Uniform FlowFlange(R) technology and automation expertise by combining multiple, new, high-throughput MOCVD reactors in a modular two- or four-reactor cluster architecture. The MaxBright reactors, based on the production-proven K465i, feature both expanded wafer capacity and advanced, proprietary, closed-loop, thermal control technology. These reactors achieve 25% higher throughput than the standard K465i, while extending proven performance advantages - uniformity, repeatability and material quality. The MaxBright MOCVD system offers industry-leading wafer capacity of up to 216 x 2", 56 x 4", 24 x 6" or 12 x 8" wafers. In addition, seamless recipe transfer from K465i to MaxBright enables customers to achieve rapid production start.

According to William J. Miller, Ph.D., Executive Vice President of Veeco's Compound Semiconductor Business, "MaxBright's value proposition is clear: it's the highest productivity MOCVD system for HB LED manufacturing on the market. The architecture enables single chamber or multi-chamber layer growth capability, increasing process flexibility for demanding LED structures. MaxBright's compact architecture also enables a footprint efficiency gain of up to 2.5 times standalone MOCVD systems. Overall, MaxBright delivers a 500% productivity gain compared to the K465i in a flexible and compact package."

John R. Peeler, Veeco's Chief Executive Officer, added, "Veeco has dramatically accelerated our MOCVD technology investment and new product development programs to further reduce LED manufacturing costs. We are excited to launch this new, high productivity system as part of our multi-generational roadmap for improving MOCVD process capability and capital efficiency. MaxBright will enable the industry to accelerate its transition to LED lighting. In 2010, the K465i became the market-leading MOCVD system. And now, MaxBright further extends Veeco's product leadership position as the most productive and lowest cost of ownership MOCVD tool on the market." ■

Jewel-Toned Organic Phosphorescent Crystals: A New Class of Light-Emitting Material

University of Michigan researcher Jinsang Kim and his colleagues have developed a new class of material that shines with phosphorescence—a property that has previously been seen only in non-organic compounds or organometallics. These pure organic compounds that glow in jewel tones could potentially lead to cheaper, more efficient and flexible display screens, among other applications.



Organic phosphors developed at the University of Michigan could one day lead to cheaper organic light-emitting diodes. Here, they glow in blue and orange when triggered by ultraviolet light. (Credit: Marcin Szczepanski, U-M College of Engineering)

Kim and his colleagues made metal-free organic crystals that are white in visible light and radiate blue, green, yellow and orange

when triggered by ultraviolet light. By changing the materials' chemical composition, the researchers can make them emit different colors.

The new luminous materials, or phosphors, could improve upon current organic light-emitting diodes (OLEDs) and solid-state lighting. Bright, low-power OLEDs are used in some small screens on cell phones or cameras. At this time, they aren't practical for use in larger displays because of material costs and manufacturing issues.

The OLEDs of today aren't 100 percent organic, or made of carbon compounds. The organic materials used in them must be spiked with metal to get them to glow.

"Purely organic materials haven't been able to generate meaningful phosphorescence emissions. We believe this is the first example of an organic that can compete with an organometallic in terms of brightness and color tuning capability," said Kim, an associate professor of materials science and engineering, chemical engineering, macromolecular science and engineering, and biomedical engineering.

This work is newly published online in *Nature Chemistry*.

The new phosphors exhibit "quantum yields" of 55 percent. Quantum yield, a measure of a material's efficiency and brightness, refers to how much energy an electron dissipates as light instead of heat as it descends from an excited state to a ground state. Current pure organic compounds have a yield of essentially zero.

In Kim's phosphors, the light comes from molecules of oxygen and carbon known as "aromatic carbonyls," compounds that produce phosphorescence, but weakly and under special circumstances such as extremely low temperatures. What's unique about these new materials is that the aromatic carbonyls form strong halogen bonds with halogens in the crystal to pack the molecules tightly. This arrangement suppresses vibration and heat energy losses as the excited electrons fall back to the ground state, leading to strong phosphorescence.

"By combining aromatic carbonyls with tight halogen bonding, we achieve phosphorescence that is much brighter and in

practical conditions," said Onas Bolton, a co-author of this paper who recently received his Ph.D. in Materials Science and Engineering.

This new method offers an easier way to make high-energy blue organic phosphors, which are difficult to achieve with organometallics.

Organic light emitting diodes are lighter and cheaper to manufacture than their non-organic counterparts, which are made primarily of ceramics. Today's OLEDs still contain small amounts of precious metals, though. These new compounds can bring the price down even further, because they don't require precious metals. They're made primarily of inexpensive carbon, oxygen, chlorine and bromine.

"This is in the beginning stage, but we expect that it will not be long before our simple materials will be available commercially for device applications," Kim said. "And we expect they will bring a big change in the LED and solid-state lighting industries because our compounds are very cheap and easy to synthesize and tune the chemical structure to achieve different colors and properties."

Former doctoral student Kangwon Lee discovered the unique properties of these materials while developing a biosensor—a compound that detects biological molecules and can be used in medical testing and environmental monitoring. The phosphors have applications in this area as well. After Lee's discovery, Bolton developed the metal-free pure-organic phosphors.

The paper is titled "Activating efficient phosphorescence from purely-organic materials by crystal design." In addition to Kim, Bolton, and Lee, other contributors are: former postdoctoral researcher Hyong-Jun Kim in the Department of Materials Science and Engineering and recent Chemical Engineering graduate Kevin Y. Lin. This work is partly funded by the National Science Foundation and the National Research Foundation of Korea.

The university is pursuing patent protection for the intellectual property, and is seeking commercialization partners to help bring the technology to market. ■

Voiding Defects: New Technique Makes LED Lighting More Efficient

Light-emitting diodes (LEDs) are an increasingly popular technology for use in energy-efficient lighting. Researchers from North Carolina State University have now developed a new technique that reduces defects in the gallium nitride (GaN) films used to create LEDs, making them more efficient.

The new technique reduces the number of defects in those films by two to three orders of magnitude -- increasing the output of light by a factor of two for a given amount of power. (Image courtesy of Lukasz Tylec)

LED lighting relies on GaN thin films to create the diode structure that produces light. The new technique reduces the number of defects in those films by two to three orders of magnitude. "This improves the quality of the material that emits light," says Dr. Salah

Bedair, a professor of electrical and computer engineering at NC State and co-author, with NC State materials science professor Nadia El-Masry, of a paper describing the research. "So, for a given input of electrical power, the output of light can be increased by a factor of two – which is very big." This is particularly true for low electrical power input and for LEDs emitting in the ultraviolet range.

The researchers started with a GaN film that was two microns, or two millionths of a meter, thick and embedded half of that thickness with large voids – empty spaces that were one to two microns long and 0.25 microns in diameter. The researchers found that defects in the film were drawn to the voids and became trapped – leaving the portions of the film above the voids with far fewer defects.

Defects are slight dislocations in the crystalline structure of the GaN films. These dislocations run through the material until they reach the surface. By placing voids in the film, the researchers effectively placed a "surface" in the middle of the material, preventing the defects from traveling through the rest of the film.

The voids make an impressive difference:

"Without voids, the GaN films have approximately 10^{10} defects per square centimeter," Bedair says. "With the voids, they have 10^7 defects. This technique would add an extra step to the manufacturing process for LEDs, but it would result in higher quality, more efficient LEDs."

The paper, "Embedded voids approach for low defect density in epitaxial GaN films," was published online Jan. 17 by Applied Physics Letters. The paper was co-authored by Bedair; Pavel Frajtag, a Ph.D. student at NC State; Dr. Nadia El-Masry, a professor of material science and engineering at NC State; and Dr. N. Nepal, a former post-doctoral researcher at NC State now working at the Naval Research Laboratory. The research was funded by the U.S. Army Research Office.

NC State's electrical and computer engineering and material science and engineering departments are part of the university's College of Engineering. ■

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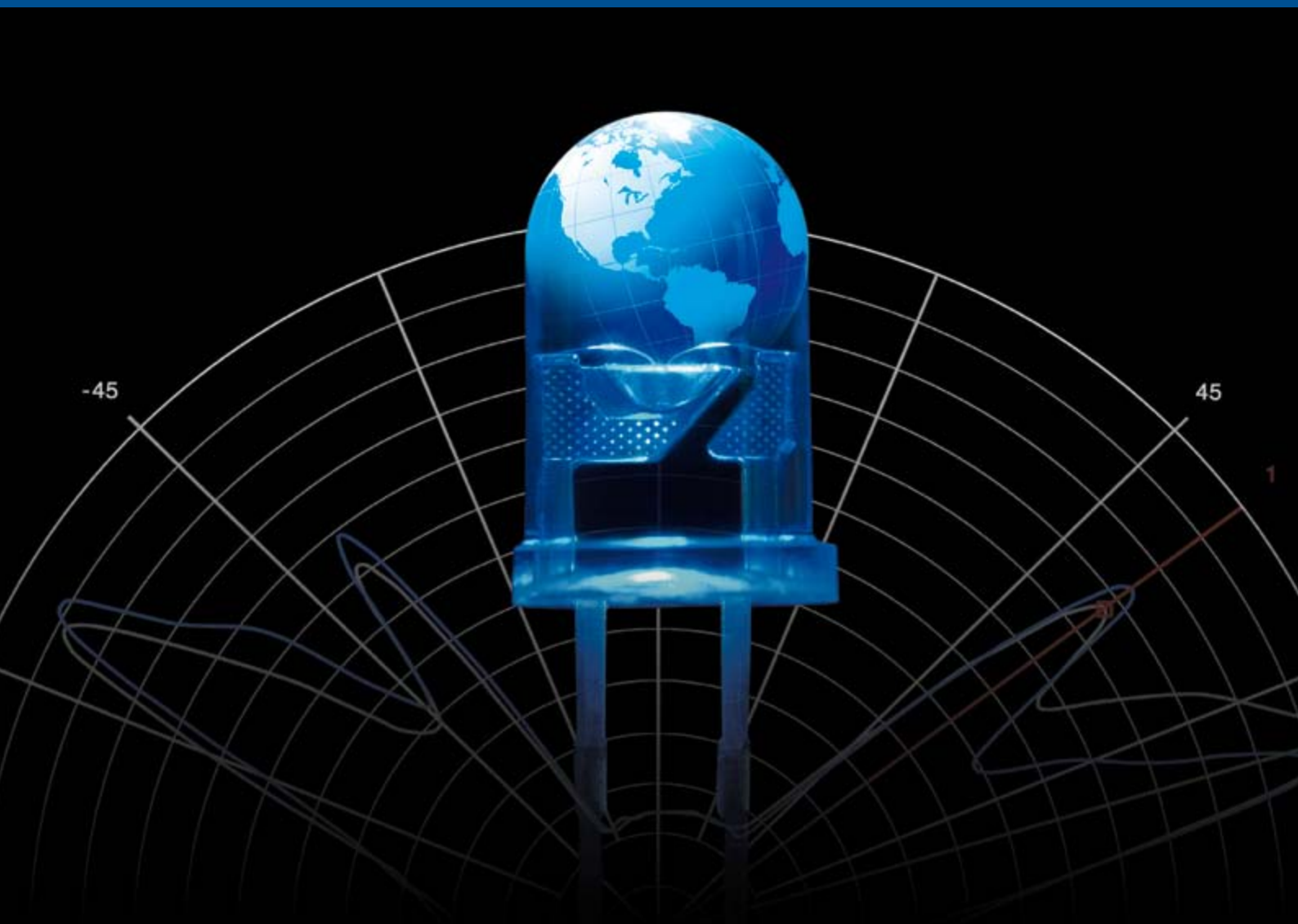
Signcomplex Ltd. has released some new outstanding products recently. Here are some examples for your information. All these products are distinguished by their high quality, excellent and steady performance, take the wall light as an example, it's of IP68 waterproof, high lumen output, steady thermal behavior. New products cover almost all usage of LED lamps like fluorescent tubes, wall light, bulb, panel light, downlight, etc.

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The Optical Plastics Make a Difference to a Lens

Arno Grabher-Meyer from LED professional discusses the role, technical properties and future perspectives of technical plastics in the LED lighting business with Peter Jackson and Tsuyoshi Okii from Styron LLC.

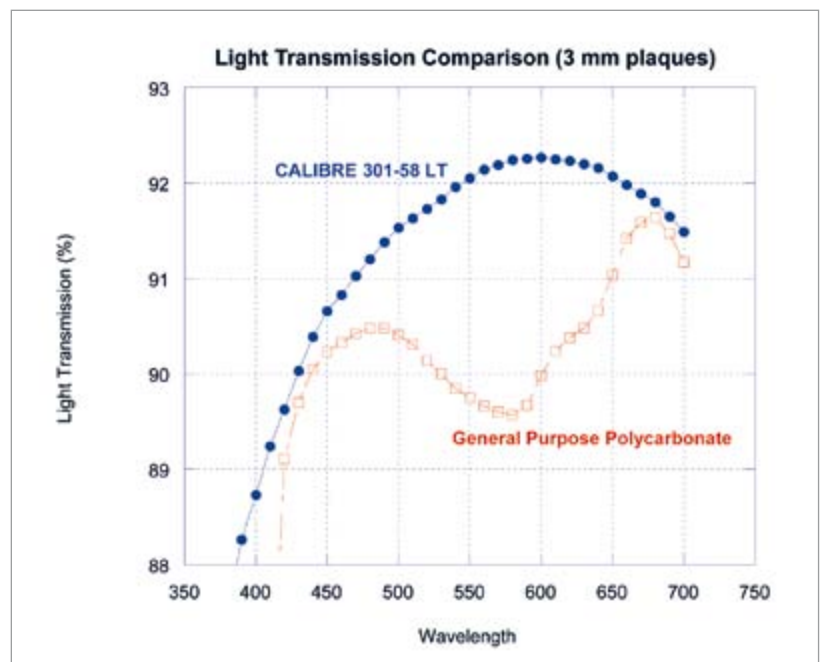
Figure 1: Only high purity grade polycarbonates offer high transmission over a wide spectral range

LED professional: Until June 2010, Styron was a part of The Dow Chemical Company. Now Styron is a standalone company as the result of the re-structuring of different business units. The Polycarbonate, Styrenics and some other divisions were merged to form Styron. When looking at the history I imagine that your company has an abundance of knowledge; the logo and the impressive slogan "We're proud of where we're from, but it's where we're going that excites us most" expresses that Styron wants to make its own way and is prepared and open for new challenges. Is the LED business one of these challenges?

Tsuyoshi Okii: Yes, it is. We have participated in the lighting market for a number of years and the changing requirements of the business are what drive us to continue to grow and develop our products and services. Our most recent example is the launch of CALIBRE™ 301-58LT and its customized versions.

LED professional: Are there special demands on this business, or is it business as usual?

Tsuyoshi Okii: For Styron, no business is business as usual. Each of our businesses has different requirements and material challenges that we address to help our customers succeed. With regards to LED lighting, the demands from our customers are centered on the new challenges in luminaire manufacturing, from the need for high light transmission and



the greater design freedom, to the possibility to control and modify bright LED lighting effects by diffusing and directing the light appropriately.

LED professional: Most of the products that resins and plastics manufacturers offer to LED lighting technology are not specific LED products. They can be used in other applications as well.

Peter Jackson: In some cases that is correct. However, our new CALIBRE™ 301-58LT and its customized versions have been tailored to meet the new requirements of LED lighting design. Specially designed manufacturing lines for this product combined with our proprietary production technologies result in a very pure product with excellent optics.

LED professional: Do you expect the LED lighting business to gain a significant portion of the whole sales volume of these products?

Tsuyoshi Okii: Basically, LED lighting is still in the early stages of penetration in lighting markets. New products specifically introduced for LED lighting such as Styron's CALIBRE™ 301-58LT are therefore specialty solutions which will eventually grow within this emerging market. While we expect there will be a range of new applications for LED lighting, we feel a substantial retrofit market for current lighting (incandescent, fluorescent and halogen) will eventually open up once LED lighting has become more cost competitive.

LED professional: How can/will the plastics manufacturers, especially Styron, influence the LED business and foster market development?

Tsuyoshi Okii: The future success of LED applications will most likely depend on the ability to overcome some specific challenges, especially (when) compared to other lighting solutions. This is particularly seen in opalescence for open space lighting. Because of their focused light source, LEDs are not traditionally seen as a viable solution for open space lighting where a diffused, soft light is generally preferred. With its optional opalescent tint helping to manage light transmission levels, Styron's CALIBRE™ 301-58 LT and its customized versions can overcome this challenge and potentially allow for energy efficient light sources in large open spaces such as offices or factory warehouses.

LED professional: The lighting market has changed remarkably because LEDs can replace most traditional light sources. New companies that, for instance, do not have much competency in luminaire manufacturing, but do have knowledge in electronics, try to gain ground in that business. Often, they don't know much about the differences in optical materials. Could you please explain which material-parameters are relevant for manufacturers and what these parameters mean? How will they affect end products or manufacturing processes?

Peter Jackson: High light transmission is obviously of crucial importance. Styron's CALIBRE™ 301-58 LT offers excellent light transmission similar to glass and very high purity due to the use of specially designed production lines for this product. Melt flow is likely to be the second most important parameter for the industry, especially when design comes into play. Resins with a high melt flow allow extra thin luminaire designs, providing product designers with a wider spectrum of design options. Another aspect of luminaire design that Styron's

CALIBRE™ 301-58 LT addresses is optometrics, meaning how the light is managed. In order to provide even more design flexibility, Styron offers CALIBRE™ 301-58 LT in customized versions with tints such as opalescence or water white. In addition, UV protection can be provided for the luminaire on request, depending on the requirements of the end application.

LED professional: Does Styron offer special services for LED lighting manufacturers to define the appropriate material parameters for the planned product?

Peter Jackson: Yes, we have a professional team of technical service and application development engineers alongside color specialists that are based at our major production locations. To ensure optimal efficiency, performance and customer satisfaction at the lowest total cost, Styron offers customized and tailor-made solutions that meet the specific requirements of your current or developmental lighting applications. This includes advanced ignition resistance, glass filling, opalescence, custom tints and self-coloring.

LED professional: Polycarbonates seem to be the favorable plastics for LED lighting optics. For luminaire manufacturers there are a lot of different aspects, starting from an LED with its primary optics, the secondary optics and design elements and housing, which can also cover optical functionality. Where else can polycarbonates (plastics) be applied?

Peter Jackson: Polycarbonate is also suitable for electrical fixtures, housings and structural parts in lighting, due to its inherent properties. CALIBRE™ polycarbonate resins offer excellent electrical properties, have best-in-class dimensional stability, are available in both transparent and opaque variations and can provide the required ignition resistance to meet international and local flammability norms.

EMERGE™ advanced resins (polycarbonate compounds) offer a great combination of ignition resistance, processability and good aesthetics. In the case of glass filled grades, they provide even better dimensional stability, very high mechanical strength and high heat distortion temperatures.

LED professional: Which Styron product is intended for the different products?

Tsuyoshi Okii: Our broad product portfolio for lighting offers both OEMs and product designers a range of options for lighting applications such as fittings, fixtures, profiles or globes. End users are transitioning to non-incandescent lighting, such as compact fluorescent lights (CFLs) and the emerging LED (solid-state) lighting, where high light transmission, opalescence and durability are key requirements. CALIBRE™ polycarbonate resins, EMERGE™ advanced resins and TYRIL™ SAN resins from Styron provide a range of tailored solutions for lighting applications, dependent on specific individual requirements.

LED professional: Styron recently introduced CALIBRE™ 301-58 LT, a polycarbonate with glass-like appearance, which was also announced on LED-professional.com. A presentation chart shows that general purpose grades of polycarbonate resins have much lower transmission than CALIBRE™ series polycarbonates in general. What are the main advantages of CALIBRE™ 301-58 LT, and is there a proprietary technology behind it?

Peter Jackson: Styron's innovative CALIBRE™ 301-58 LT resin combines high light transmission similar to glass, with high melt flow, making it an ideal solution for LED lighting applications. Our proprietary production technologies result in a very pure product with excellent optics due to the use of specially designed manufacturing lines for this product. The resin's high melt flow and excellent processing characteristics enable



Tsuyoshi Okii

Tsuyoshi Okii is the Global Marketing Manager for Electrical & Lighting at Styron. Okii-san joined Dow Japan in 1991 and assumed different roles as account manager and product marketing manager. In his current role, Okii-san works closely with the Styron Plastics Sales, TS&D and R&D teams and provides key market information to align market trends with the development of a robust R&D pipeline.



Peter Jackson

Peter Jackson is a Senior Application Development Specialist with Styron Plastics Europe. Peter is a qualified Materials and Mechanical Engineer and has worked in the polymer and automotive industry for more than 35 years.

thinner lighting designs, providing product designers with a wider spectrum of design options to shape the future of LED lighting. In order to provide even more design flexibility to luminaire designers and manufacturers, Styron now offers CALIBRE™ 301-58 LT in customized versions with opalescence or tints like water white, a requirement for many modern luminaire designs. In addition, UV protection can be provided on request, depending on the requirements of the end application.

LED professional: Styron also offers a UV stabilized version of polycarbonate. Overall visible light transmission is lower than it is for natural grade polycarbonate. When do you recommend using UV stabilized polycarbonates?

Peter Jackson: Due to the long lifetime of LEDs, which is unparalleled in today's lighting applications, certain LED lighting may require high durability. Whilst LED lights do not radiate UV light, and although no direct UV levels may be detectable, in some cases some low-level UV exposure can still occur. In these instances protection for long-term installations is advisable. That's why Styron can provide UV tailored versions.

LED professional: While LEDs do not radiate UV light, ambient light usually includes UV light. Isn't UV stability critical in any LED application, due to the long system lifetime?

Peter Jackson: No, it is not critical to performance as such, but it is desirable if the end requirements ask for maximized long-term quality and durability.

LED professional: Styron is able to offer other customized polycarbonates. Is this one of the major strengths of Styron?

Tsuyoshi Okii: Yes. We have a broad portfolio of CALIBRE™ polycarbonate and EMERGE™ polycarbonate or advanced resins which are suitable for a broad range of applications and can be further tailored as seen with CALIBRE™ 301-58 LT.

LED professional: Which parameters can Styron customize?

Peter Jackson: We can customize the following parameters: flame retardancy, reinforcement, melt flow rate, mould release, color and tints, UV resistance, opalescence and fluorescence.

LED professional: Can customers also define the grade of such a parameter, for instance, the opalescence?

Peter Jackson: Yes, for added flexibility, we offer master batches. In the case of opalescence for example, we can allow customers to determine the degree of this effect in the final product.

LED professional: Besides the optical plastics, there are many other applications for plastics. Plastics with new or improved properties are developed every day. I just think of thermally conductive plastics, and the like. Is Styron also working on materials that could be useful for LED lighting issues?

Tsuyoshi Okii: Styron has a strong product development pipeline and will continue to leverage innovations across different industries.

LED professional: Can you tell me which other future developments in plastics for LED applications do you expect or have planned?

Tsuyoshi Okii: For confidentiality reasons, I cannot comment on details.

LED professional: Thank you very much for giving us insight into plastics technology and Styron's prospects for LED lighting. ■



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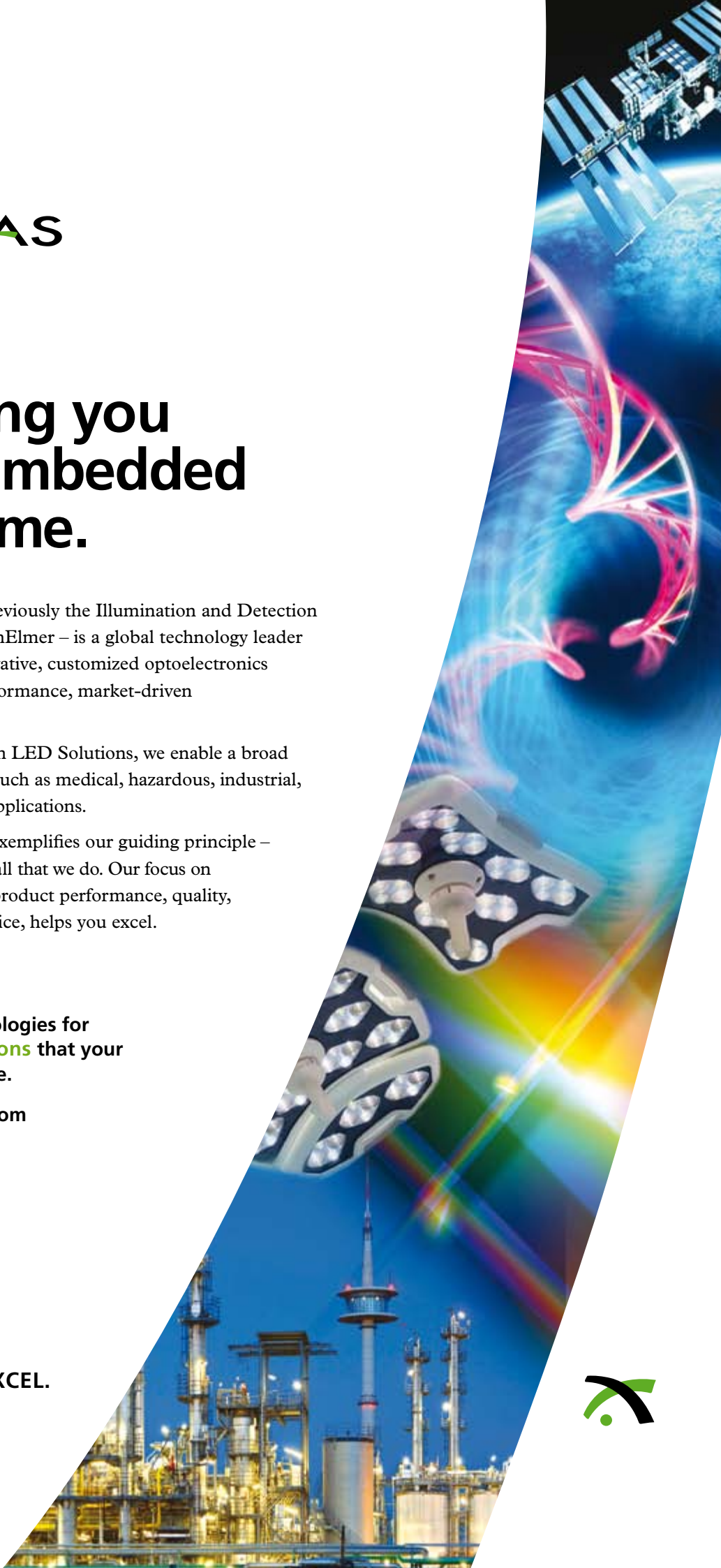
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Active Cooled 75 to 100 W Equivalent LED Retrofit Bulbs

Istvan Bakk, Project Manager Light Engines at Tridonic and Brandon Noska, Applications Engineering Manager at Nuventix discuss an active cooled approach to reach 75 W and 100 W incandescent equivalency in warm white LED retrofit bulbs with high CRI and CQS scores as well as a high efficacy above 75 lm/W.

By the term equivalency of incandescent bulbs we generally understand lm equivalency at much higher efficacy. However customer expectations relate to more equivalency even if it is not exactly drafted:

- Lighting measures: intensity, color temperature, color rendition quality, distribution of light.
- Time dependence: immediate turn on, no warm-up effects, constant light level, flicker is not higher than the incandescent, constancy of measures over lifetime, lifetime 10-50 times higher.
- Size and design: the size, outline should fit the incandescent, having neutral appearance, color, and no observable effects of weight difference.
- Electrical: no sensitivity on numbers of switching, compatibility with existing dimmer, at least 5 times lower power consumption, near resistive load (PF~1.0)
- No noise, no maintenance work, no features to learn
- Fitting to every luminaire [1]
- Price

Engineers getting the above requirements may come up with the idea of an electrically heated tungsten filament. Applying LEDs in the form factor of incandescent bulbs is a challenge, and some compromises have to be made. One thing is clear: the purpose of the bulb is lighting, so the experience of light after retrofitting an incandescent in the room cannot be altered. In the following work we would like to present an approach to

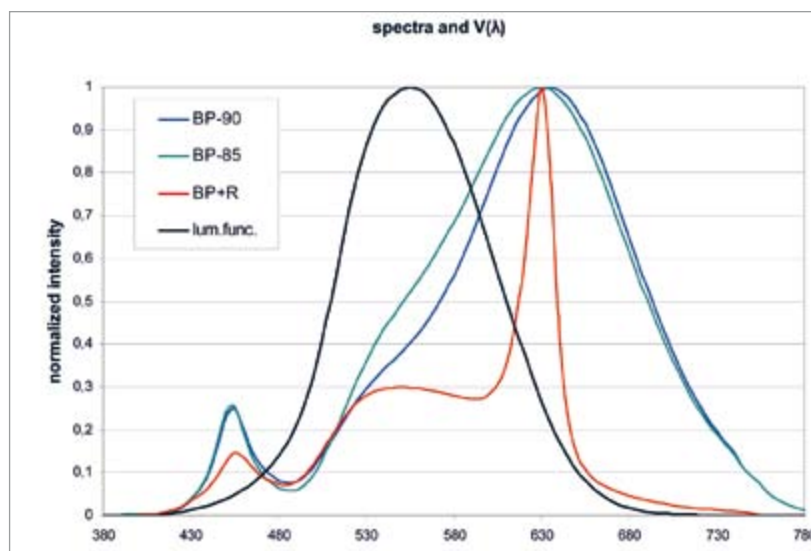


Figure 1: SPD of phosphor only and phosphor-red LED light sources

reach, and go a bit beyond the equivalency of a 75W and a 100W incandescent bulb. The study relates to a concept prototype leaving enough work for developers to get a product on store shelves.

Light Source Used in the 75 W and 100 W Equivalent Bulbs

Spectral efficacy and performance

The general approach, to reach a color temperature of 2700 K is the application of a yellow and red phosphor blend on the blue die. In Figure 1 the SPD are shown of two such phosphor compositions (YAG + nitride) having CRI 92 and CRI 85 by a blue (BP-90) and green (BP-85) curve respectively. The black curve is the

luminosity function [2], showing clearly that a significant portion of the power distribution of such solutions (phosphor only) fall to wavelengths, over 650nm, where the sensitivity of the eye is minute. Having no narrow band red phosphors suitable for such a setup, we have taken a red die instead. The spectrum of the YAG converted blue and red die solution is shown by the red curve (BP+R) on Figure 1. In other words 1 W radiant power of CRI 92, CCT 2700 K light equals to 240 lm by using a phosphor only solution, and 355 lm if we use the phosphor + red die approach. In addition, by converting blue light to red by phosphors, 1/3 of the energy is lost due to the energy difference of the photons (Stokes shift), which is not the case when converting electrical energy to light directly by a red die [3].

Color quality

The impression of the illuminated room should be the same, when an incandescent bulb is replaced by a light-source having a different spectrum. This is difficult to evaluate by measures. It is commonly accepted, that CRI is inadequate to evaluate the color rendering of normal objects and modern pigments [4]. A new measure, CQS, has been developed based on 15 Munsell samples to create a high chroma and span the entire hue circle [5]. The CQS results of the above shown spectra of phosphor only (BP-90, BP-85), the phosphor+red die (BP+R), an incandescent bulb (INC) and a common three-band compact fluorescent lamp (CFL) are shown in Figure 2. To evaluate the visual impression, color preference [6] and color fidelity are found to be important factors [7] to be weighted [8]. Lacking a commonly accepted measure, experts still use live booth experiments [9]. The live experiment results and the CQS evaluation prove that the selected technology (BP+R) is one of the best known candidates to mimic the incandescent spectrum.

Figure 2:
5 blue phosphor +
4 red LED module



Intensity and efficacy

Modules having the above mentioned spectrum have been built in the prototypes (Figure 2), using 5 blue dice with color conversion material (yellow globe-tops), and 4 red dice (opaque globe-tops). The modules have been built in the standard method: dice are placed on an aluminum-IMS PCB, with dispensed silicone globe-tops.

The average performance data of the modules are shown in Figure 3: lm value and lm/W value in the function of supply current at 25°C heat-sink

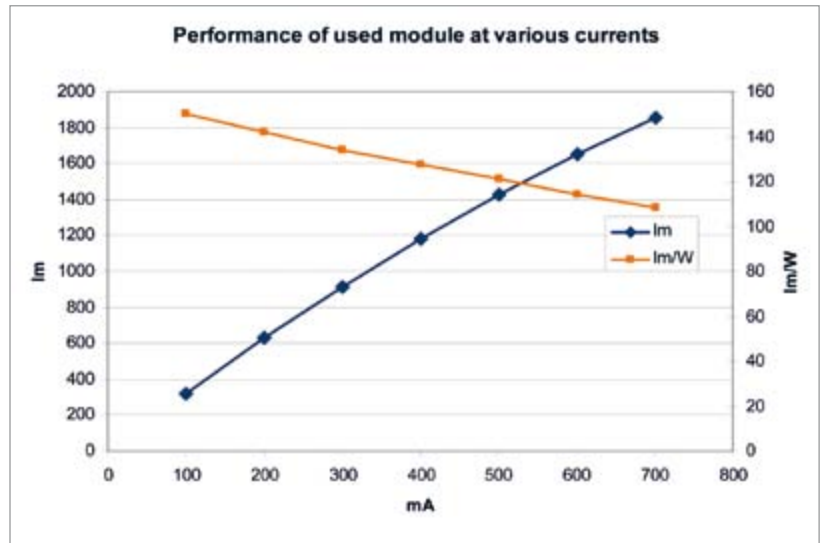


Figure 3: Luminous flux and efficacy of 5BP+4R

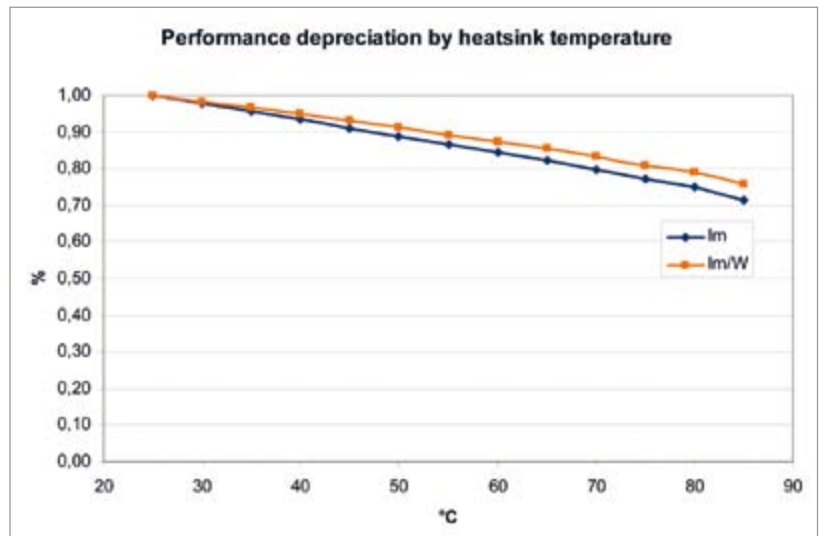


Figure 4: Thermal de-rating of 5BP+4R

Test method	Reference colors	BP-90	BP-80	BP+R	INC	CFL
CRI		92	85	92	100	83
CQS		76	78	92	98	77

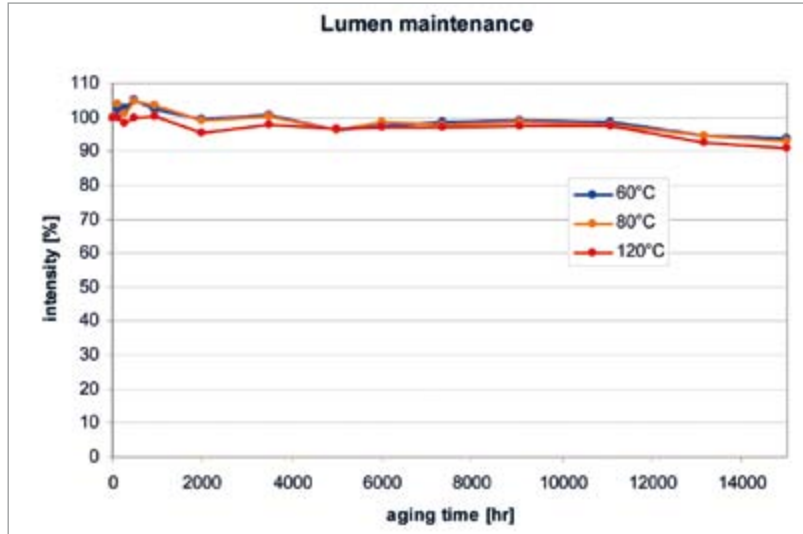
Table 1: CRI and CQS scores of various light sources

temperature. The performance depreciation at typical currents (300-600 mA) in the function of temperature is shown on Figure 5 [10].

For the 75 W equivalent (typical 900 lm, 1050 lm in standards) we have taken one module and aimed 1200 lm out of the thermally stable bulb, for the 100 W equivalent (typical 1300 lm, 1521 lm in standards) we have taken two modules and aimed 1700 lm out of the thermally stable bulb. We assume the

following parameters: heat-sink temperature to be in the range of 50-75°C, (relates to 10-20% thermal lm de-rating), 5-10% absorption losses on the dome, and 85-90% conversion efficiency of the driver electronics. To reach the aimed lm values and be in the required temperature range, the apparent thermal resistance of the heat-sink (module to ambient) should be in the range of 3 K/W. Having higher temperatures will lead to decreased lm values and color

Figure 5:
15 khr lumen maintenance of BP+R modules at various heat-sink temperatures



temperatures outside the range. On long term the failure rate of the module increases (however the higher probability of failure is in the driver components). It is worth it to mention that according to the long term measurement data of such modules (Figure 5) the lumen maintenance is expected to be within specifications (L70 @ 30 khr) even at elevated temperatures. The lm values at 15 khr are above 90% of the initial values even at 120°C heat-sink temperatures. The chip-on board technology, used at these modules allows having a thermal resistance of 6-8 K/W from junction to heat-sink that presents a very attractive conduction scheme at high powers.

Thermal Solution

The size and shape of retrofit bulbs are defined by existing norms. Looking at the A60 geometry, depending on the passive cooling solution and orientation, a range of 6 ± 1 K/W of apparent system thermal resistance can be realized. Assuming the ambient conditions of 45°C (for example a recessed or not-well-ventilated fixture type), an A60 retrofit lamp would need a system thermal resistance of 3 K/W, thus allowing a $\Delta T_{\text{heatsink-ambient}}$ of 50°C for good performance and reliable operation (F10 @ >30 khr). These conditions cannot be met with a passive heat sink. Such values can't be achieved:

- The Nusselt number is too low for the following reasons: the flow is near laminar, there is poor intermixing between "flow layers" perpendicular to the airflow and the heat transport is diffusion dominated, leading to a high temperature drop at the interface.
- The mass flow rate is low; therefore, the transported heat is too low.

To circumvent these reductions of natural convection, active cooling methods can be selected. In our applications the heat transfer is not limited by the mass flow (heat capacity of air), but the high temperature drop at the heat-sink to air interface (resulting in low Nusselt number). An attractive method, that passes to our requirements are the application of

synthetic jets, that create high turbulence on the surface, which increases the Nusselt number, and create an entrained, secondary, airflow directly on the outer surface. Synthetic jets created from electromagnetically driven actuators have no parts in friction, no lubricants to breakdown, and no mechanical wear. Can be operated at low frequencies thus the acoustics are virtually silent. The flow at the actuators is bidirectional, avoiding dust accumulation; however, the resulting flow is directional and turbulent resulting in high heat transfer. The reliability is high, available at low cost and various form factors [10].

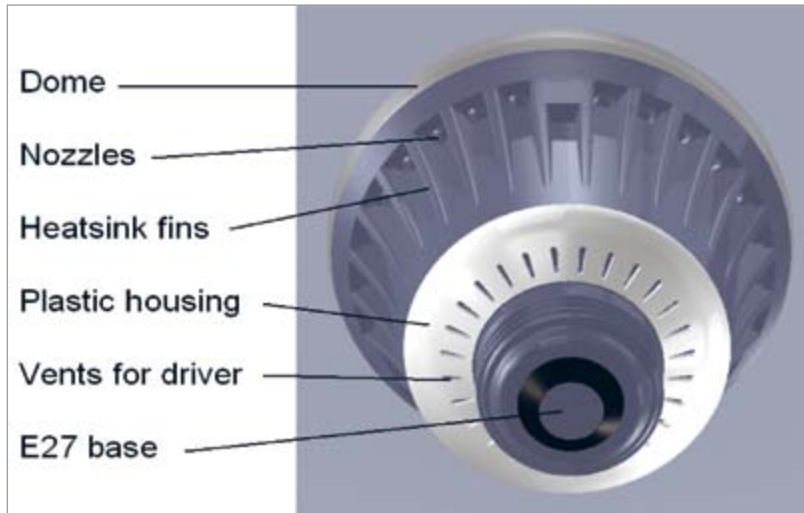
Mechanical Setup

The Synthetic jet engine is located in top-side of the bulb (Figure 6). Above the Synthetic jet engine is a heat spreader. This heat spreader has several functions including conducting the heat from the LED module to the finned heat sink, forming nozzles which create synthetic jets and distribute the airflow to the heat sink fins acting as a primary heat exchange with the pumped air. The heat spreader is in good thermal contact with the heat sink surrounding the bulb. For the purposes of this prototype, the heat sink is kept raw, however it can be painted to improve radiative properties. The nozzles above the Synthetic jet engine are radially distributed (Figure 7) at the edge of the

Figure 6:
Cross section of the prototype bulb



Figure 7:
Bottom view of the prototype bulb



heat sink, between the fins to allow the synthetic jets to achieve a good heat exchange with ambient air. In order to cool the driver electronics, one chamber of the Synthetic jet engine is connected to the plastic housing of the driver. On the bottom of this housing, vents are opened to allow the exchange of air, thereby cooling the driver electronics.

Active Cooling Process

The active cooling process with the SynJet engine can be divided to two phases, which repeat periodically at a frequency of 40 to 50 Hz. In Phase 1

(as shown in Figure 8) the two membranes expand, increasing the air pressure in the outer chamber and creating an airflow that pushes jets of air through half of the nozzles surrounding the heat sink. The jets drag (entrain), a secondary airflow, from the ambient air, creating a turbulent, high flow stream of air which propagates along the heat sink, towards the base of the bulb. At the same time, the pressure decreases in the inner chamber causing cold air to be sucked in from the top side of the bulb through the second set of nozzles. In phase 2, the opposite process occurs. The membranes

contract so air flows to the bulb through the first set of nozzles and synthetic jets are formed on the second set. Since the membranes move in the same phase, but in opposite directions, no vibration or resonance occurs to the bulb. Since the drive frequencies of the membranes are low, the resulting acoustic signature is near silent.

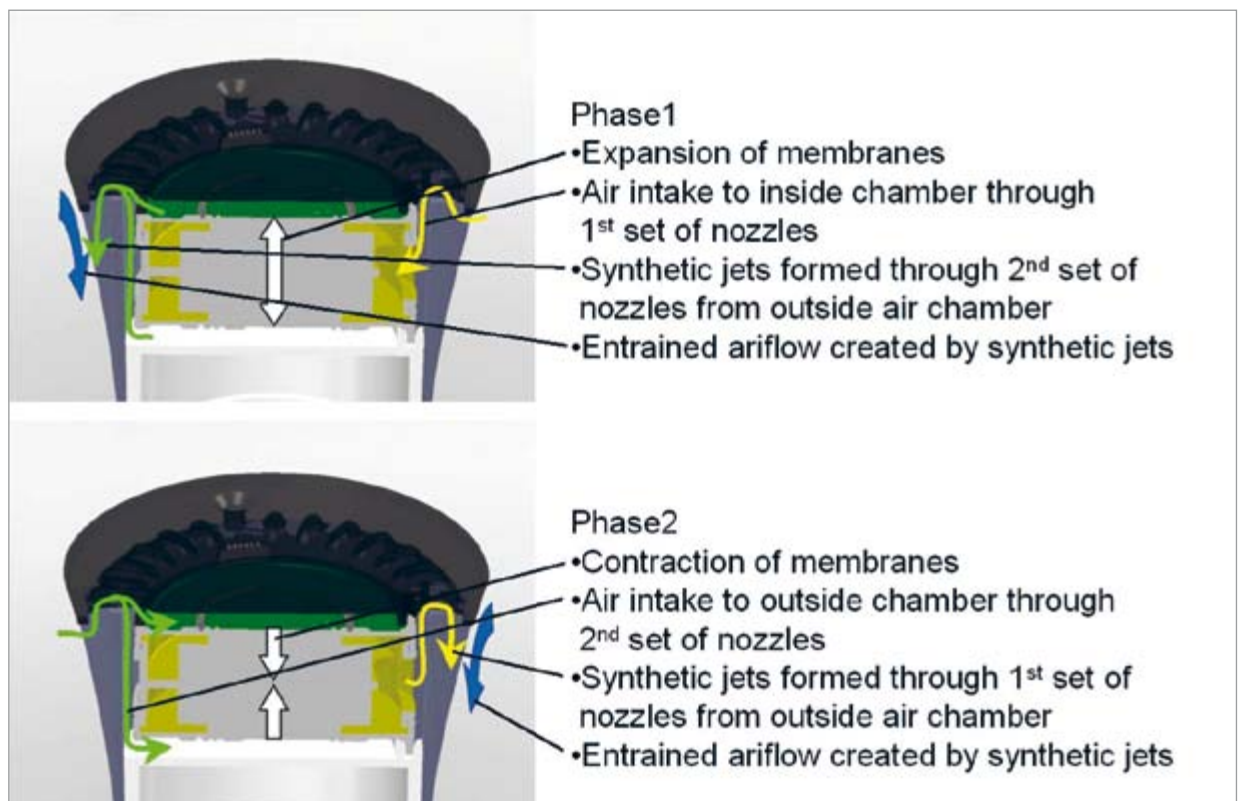
Driver Electronics

The major requirement for electronics is first of all a high conversion efficiency, which reduces the cooling effort to be provided for the driver. The driver should supply the LED string with constant current, while the synthetic jet engine needs constant voltage. Low complexity is preferred for higher reliability, if protection is addressed properly.

Version	Power consumption of LED	Power consumption of SynJet engine
1200 lm	13.8 W C.C	0.2 W C.V.
1700 lm	17.6 W C.C	0.5 W C.V.

Table 2: Power consumption of the 75 W and 100 W equivalent LED bulb

Figure 8:
Jet formation mechanism in the prototype bulb



A quasi-resonant flyback type converter [12] has been used in primary controlled mode, and isolated topology. A phase-cut dimming feature is implemented in the driver, that has high efficiencies even at dimmed levels ($\eta=0.7$ at 10%). The direct dimming mode, and primary control allows a very low list of passive components: for filtering, rectifying, power storage (against ripple), and current setting. This way the size and complexity of the driver is kept low. The supply of the active cooler was solved by a second secondary winding on the transformer. The controller IC addresses the required features of integrated PFC control, over-voltage protection, over-temperature protection, and driver supply voltage protection, LED string open and short protection. The primary control allows a low tolerance set of power control, thus the power of the bulb, and the heat dissipation is controlled in every case. If the active cooling stops for any reason, the controller IC would reach its temperature shut down earlier than the breakdown of any other components (LED string, rectifying diode, transformer), which we have tested in various conditions.



Measure	Version 1	Version 2
Warm white Light Flux	1200 lm	1700 lm
CRI	92	92
CCT	2690 K	2700 K
Electric Power	16 W	21 W
Power Factor	0.94	0.92
LES	75 lm/W	81 lm/W
Noise level	17 dbA	19 dbA
Number of dice	5 blue (white) + 4 red	10 blue (white) + 8 red

Table 3: Specification of the 75 W and 100 W equivalent LED bulb

Conclusions

The performance of the bulbs was set to show, that 75 W and 100 W equivalence can easily be reached by the applied module, active cooler and electronics. All values are measured in a temperature stable state, after 60 minutes of warm up at 25°C ambient. It can be seen, that there is a freedom to vary the parameters. For example lumen values of version 2 can be further increased in the system beyond 2000 lm with stable thermal conditions, but an efficacy drops to 75 lm/W. Moreover, noise level can be

further decreased by smoothing surfaces; the radiated heat transfer can be increased by painting, just to mention a few measures. Architectural design can be improved a lot, too. However, the aim of this concept study was not to reach the edge values that are enabled by the technology, but to show the industrialization potential of the used components to get real equivalency. ■

Acknowledgement:

The financial support from the Klima- und Energiefonds is gratefully acknowledged.

References:

- [1] DIN EN 60630
- [2] Eye sensitivity curve at photopic conditions
- [3] This is the approach of all XED bulb modules: <http://www.tridonic.com/com/en/products/xed.asp>
- [4] Davis, W. L.; Ohno, Y, Proc. Sixth International LRO Lighting Research Symposium, Orlando, 2006
- [5] Not only the sample colours differ, but the test source, colour space and calculation scheme to calculate the difference in colour appearance to correct flaws of CRI: for details see paper in ref.4
- [6] It is worth to mention, that colour saturation is preferred, having decreased intensity at the overlap of M and L rod cell sensitivity curves (580 ± 20nm) lead to a more contrasted and saturated colour perception. This effect is used at GE Reveal bulbs, and the BP+R approach.
- [7] Other factors as: colour harmony, colour saturation, gamut area scale, and so on could be investigated too, but proper weighing is a challenge
- [8] See CIE TC 1-69: "Colour rendition by white light sources"
- [9] http://www.ledon-lamp.com/en/ledon_lighting_quality.htm
- [10] The separation of lm and lm/W curves is due to the decrease of forward voltage at higher temperatures
- [11] The Nuventix SynJet is the only synthetic jet solution for LED cooling, reliability papers and references are available at the company website: www.nuventix.com
- [12] www.infineon.com/applications/icl8001g

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Re-Thinking a New Power and Control System for LED Lighting

Mark Covaro, CTO and Co-Founder of Redwood Systems examines a new power and control architecture for commercial lighting, designed around the specific constant current, DC power properties of LED lighting.

Over 125 years ago, the world's first power systems for lighting were direct current (DC) power grids developed in the 1880's by the Edison Electric Illuminating Company. These systems were used to provide electric light to approximately 800 of Edison's early commercial customers. The location at Pearl Street in central Manhattan was a strategic one - DC power did not efficiently travel long distances - and this inefficiency would eventually put Edison on the losing end of a "A War of The Electric Currents" that favored higher voltage alternating current (AC).

A century later, AC is the global standard for both long distance transmission and the distribution of power within commercial buildings and homes. Yet, today's AC mains have not served as an effective medium for digital communications, and most attempts to create power-line communications on AC wiring have proven to be difficult, complex and unreliable. As a result, most commercial and residential electrical applications do not communicate over the electrical wiring, and any network or system-based techniques to optimize power consumption, or even measure and monitor electric power at the application level, must be added as expensive and cumbersome overlays. In essence, without the ability to



Figure 1: Centralized LED Driver and Control Engine

communicate, these electric loads all connect to an "analog" network – one that can deliver power as needed but cannot know why devices came on, the optimum power to provide, when they are going to go off, if they are failing, over-heating, working improperly, have power losses or issues in the wiring, or even how much power each application is using.

For fans of Thomas Edison, the greatest irony is that there are now several household and commercial applications that are inherently "digital" in nature, and that require DC power, including the expanding markets and applications for light emitting diode (LED) lighting, that could utilize a digital systems approach to improve energy efficiency, but remain plugged into a strictly analog AC power line.

With the growth of LED lighting, and the need for AC/DC conversion at every light, there is an opportunity to re-think lighting, and design a new lighting power and control system that combines the LED driver functionality

typically deployed on a per-fixture basis into a larger, aggregate driver that can power up to 64 fixtures. Similar in architecture to "power-over-Ethernet (POE), but delivering the constant-current power needed for LED fixtures, this new system completely replaces all AC wiring for LED office lighting with DC power networks.

By utilizing novel communication techniques, this same centralized driver can offer integrated two-way communications to LED fixtures, making this aggregate driver serve as a unified power and lighting control system. Combined with sensors attached to each and every fixture, this fully sensed and intelligent power fabric can both improve the LED driver system required to power the lights, as well as deliver lighting control capabilities, smooth, 64,000 step digital dimming and sensor data that can maximize energy efficiency for lighting and smart building applications.



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There are three major benefits of this system over traditional lighting control “overlays” that are deployed as separate systems from lighting power. First, this new architecture delivers fine-grained lighting control techniques found in DALI, DMX, and other advanced lighting control platforms – occupancy sensing, daylight harvesting, task tuning, individual user control, and demand response and peak load control – as well as new smart lighting techniques and improved energy efficiencies found by centralizing the driver. We will cover some of those opportunities for improved driver efficiency below. Secondly, by deploying multi-way sensors on a per-fixture basis, this system introduces several new smart building applications enabled by this high-resolution sensor data collection. For example, detecting temperature at each fixture provides the system with comprehensive room, zone, and floor level data on thermal comfort, and with integration into building management systems (BMS), the ability to better report, control, and optimize heating and cooling systems. Lastly, by incorporating low voltage cabling instead of AC wiring, and by removing the need for LED drivers at each fixture, this system can significantly reduce costs for controlled LED lighting applications.

Power Architecture

The core of this new architecture is an aggregate LED driver capable of driving up to 64 LED luminaires of 20 W of power each from a single

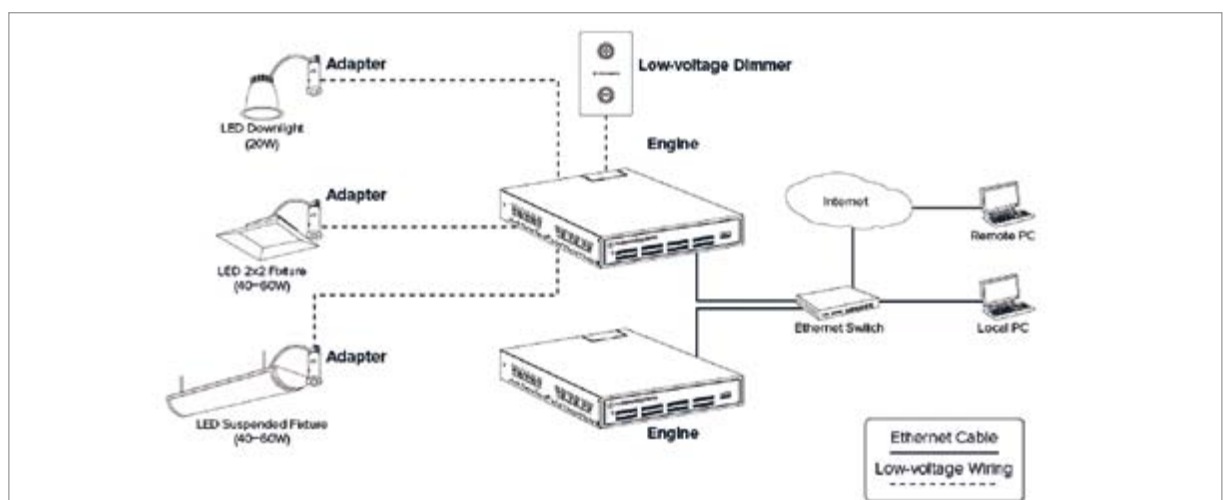
“engine” appliance via low voltage connections called “channels”. For fixtures that require more than 20 W, the engine can combine multiple channels and provide 40 W or 60 W respectively for fixtures that need higher wattage. The first generation of the engine is designed for placement in a utility area such as a data and telecom closet. It can accept either 120 VAC or 277 VAC (see Figure 2). The design permits the replacement of the AC inlet modules with modules that will accept DC, such as a solar or battery feed. The AC inlet provides some amount of power conversion as well as power factor correction and power filtering. There are eight of these inlet modules, each of which powers eight of the output channels. This arrangement is useful in the event of a failure. Power is measured at the inlet and outlet of these modules.

Concentration of all of the power channels into a single unit provides some economies of scale for the electronic design. This in turn improves the reliability and efficiency of the system. It also differs from the conventional power arrangement currently available for luminaires. Currently, if a ballast or LED driver fails, an electrician must be scheduled to come on site and make the repair. A failure can be repaired by moving a pair of wires to an empty channel. Because of the nature of the software, this creates a minimal disruption to the system and can be done by anyone on site due to the Class II nature of the system.

Communications and power are integrated together on each channel. Each channel is also low bandwidth, which allows the power and cost to stay low while still being satisfactory for lighting applications. Special modes are embedded in the communications to reduce latency for critical event, such as motion detection. Channels provide from 75 to 500mA of current to the luminaire. The channels are limited to never provide more than 60V at their output. This limits the maximum forward voltage at the luminaire to approximately 52V. The difference is allocated to component tolerances and power line voltage drops. Power is measured at the output of each channel.

The engine contains a processor board which provides Ethernet communication to the data network and controls the power and communications to the luminaires and their adapters. This is one of the key cost advantages for the system design – the cost of the processing and control is amortized into a single centralized board which controls 64 LED drivers. This design affords a very fine level of control over the output of the channel with very low cost. Each channel is capable of 65536 (16 bits) levels of brightness. In addition, it is possible to apply different dimming curves, such as a logarithmic curve which matches the behavior of the eye.

Figure 2:
Architecture for Networked Based LED Power and Control System



Electrical Input Specifications

Figure 2 and Table 1 enumerate the key electrical design parameters to which each LED chain should be constrained. Up to three channels can be connected to three electrically isolated LED chains in a single luminaire.

Adapter

An adapter resides at every luminaire. The adapter allows the combination of up to three channels so that a 60W luminaire may be supported. It contains a motion detector, two light level detectors, voltage and current sensors, and an onboard temperature sensor. The adapter also has an input for a temperature sensor on the luminaire. The luminaire temperature sensor may be used to evaluate the temperature of LEDs on the luminaire. The adapter also passes power from the engine to the luminaire. Current and voltage are sensed for every channel in the adapter so that power can be measured at the luminaire, and ensure that no fixture is attached with improper gauge or voltage losses that could cause problems powering the fixture. A circuit on the adapter sips a small amount of power from the channel as it goes to the luminaire. This circuit powers a microcontroller used for the communications with the engine as well as housekeeping and parameter measurement on the adapter.

Additional adapter designs are underway which contain different sensors. CO, CO2, VOC (volatile organic compounds), LPG (propane), natural gas, pressure, particulate, air velocity, humidity, and RGB sensors are examples.

Controller System

An easy-to-use graphic user interface (GUI) for user control is provided. The engine can also be controlled with lower level messaging through the Ethernet ports if desired. The GUI presents a unified interface as a web browser. No special software is needed anywhere, the system interface is a web page. This web page allows for control and measurement of the system. The user is able to identify luminaires and group them along with wall switches or dimmers that may or may not be present.

Designed as a platform that includes both the power hardware and control software for managing the lights, the system can also measure and optimize building performance applications from this sensor network. For example, the system can tie into calendaring software, and inform those programs when conference rooms have been booked, but not occupied. Another example of a building performance application derived from this system is the ability to report and alert on rapid temperature changes in a data center that could indicate that a door has been left open between a cold aisle and a hot aisle, a configuration typically deployed in data centers.

Figure 3: Channel to LED chain connections, see Table 1 for parameters at point A

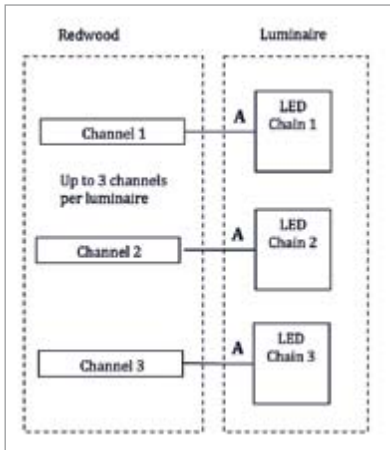


Table 1: Electrical design parameters at each point A in Fig. 2, the input to each LED chain

Item	Symbol	Value
Input Current – Maximum	$i_{in,max}$	500 mA
Input Current – Minimum	$i_{in,min}$	75 mA
Input Voltage – Maximum	$V_{in,max}$	51.9 V
Input Voltage – Minimum	$V_{in,min}$	12 V
Input Power - Recommended Max*	$p_{in,recommended}$	18.8 W
Input Power – Absolute Max*	$p_{in,max}$	25.9 W

Figure 4: Web-based interface for managing lighting levels, control policies, and reporting

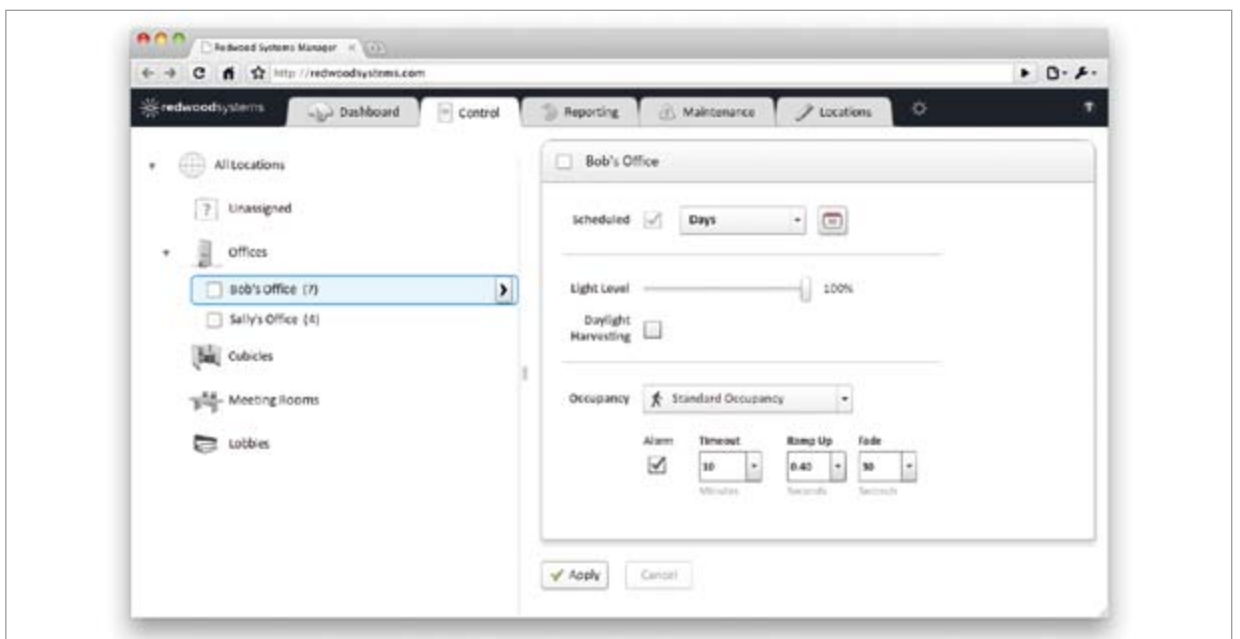


Figure 5:

Circuit 1 - A channel is powering an LED chain in series. The desired input current, i_{in} , into the chain is 350 mA. This is within the bounds of $i_{in,min}$ and $i_{in,max}$. To achieve this, the input voltage, v_{in} , may range from 45.45 V to 49.05 V, depending on the sum of the forward voltages, v_f , of each LED. This range is within $v_{in,min}$ and $v_{in,max}$. The maximum power that the chain may need from the channel is thus $v_{in} * i_{in,max} = 17.17$ W, which is below pin, recommended

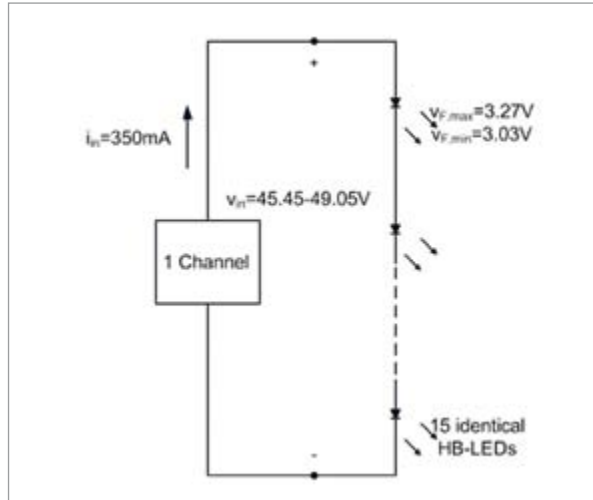


Figure 6:

Circuit 2 - A channel is powering an LED chain in a parallel-series arrangement. The desired input current, i_{in} , into the chain is 320 mA, such that each branch gets 80 mA. This is within the bounds of $i_{in,min}$ and $i_{in,max}$. To achieve this, the input voltage, v_{in} , could be up to ~50 V, depending on the sum of the forward voltages, v_f , of each LED and the resistance of the buffer resistor (this buffer resistor is optional). This range needs to be within $v_{in,min}$ and $v_{in,max}$. The maximum power that the chain could need from the channel is thus $v_{in} * i_{in} = 16$ W, which is below the recommended pin

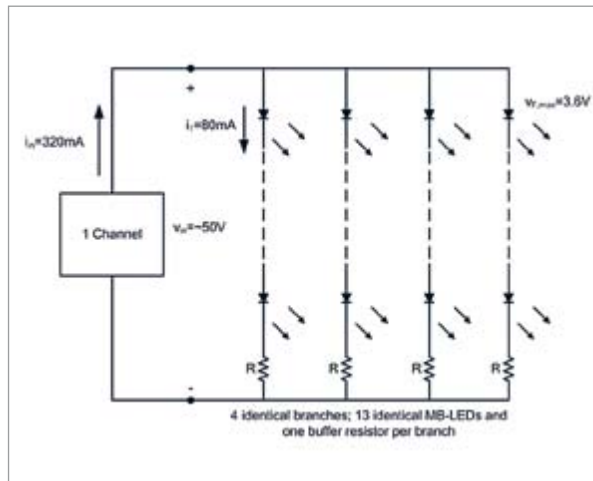
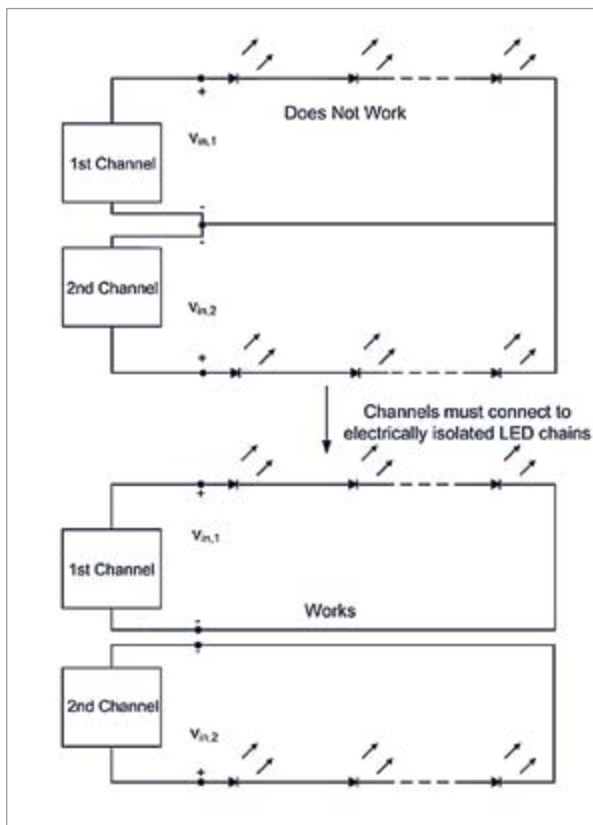


Figure 7:

Circuit 3 - As this diagram shows, channels must connect to LED chains that are electrically isolated from each other. Also note that the two LED chains need to be physically arranged so that there is not too much capacitance between them as discussed previously



LED Chain Design Examples

Circuit 1 and 2 show two LED chain examples that meet the electrical design parameters described in Table 1. HB-LEDs shown in the circuits are typical high-brightness LEDs and MB-LEDs are typical mid-brightness LEDs. Circuit 3 shows a situation that is not compatible with Redwood, and a solution to this situation. These designs are for reference only.

Conclusions

For all intents, we are wiring our lights to power systems that haven't changed much since the late 1880s. These systems use high voltage AC insulated wiring, parallel circuits, voltage regulators, and circuit panels, all of which were patented by the Edison Electric Illuminating Company. Yet, LED lighting presents a new, discretely digital, low-voltage DC lighting source. By utilizing a new, network-based approach to wiring, powering, and controlling these lights, a new systems approach can provide more fine-grained control with high-resolution control over light levels, motion and occupancy/vacancy detection, and highly customizable and programmatic dimming. Furthermore, such a system, by removing LED drivers from fixtures, and replacing AC wiring mains with low-voltage wiring can reduce end-user costs for both the fixtures and LED lighting installation, and at the same time, enable and report data to improve other building assets and resource utilization. ■



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Advanced Lighting Technology Needs an Advanced Color Rendition Metric

The need for the development of new metrics that adequately assess color rendition properties of illumination, including that by solid-state sources is discussed by Artūras Žukauskas, Rimantas Vaicekauskas from the Vilnius University and Michael Shur from Rensselaer Polytechnic Institute. The authors present an alternative approach.

For many decades, the color quality of illumination provided by artificial light sources has been characterized by the Color Rendering Index (CRI), a metric that compared how a light source reproduced a few standard colors in comparison with a reference source. This metric was primarily developed for broad-band fluorescent lamps. The emerging solid state lighting technology uses phosphor conversion (pc) light-emitting diodes (LEDs) and LED clusters usually having narrow-band spectral components. Numerous experiments evidenced a conflict between the subjective rating of such solid-state sources and CRI. Therefore, in 2007, the International Commission of Illumination (Commission Internationale de l'Eclairage, CIE) conceded the inapplicability of CRI 'to predict the color-rendering rank order of a set of light sources when white LED light sources are involved in this set' [1].

The need for the development of new metrics that adequately assess color rendition properties of illumination, including that by solid-state sources, became evident.

CRI is based on color shifts in the $U^*V^*W^*$ color space, which is actually now considered as obsolete because it is far from being uniform in respect of perceptually resolved color differences. Color shifts for 14 test color samples are estimated when a reference blackbody or daylight phase illuminant is replaced with the source under assessment. The main figure of merit, the general CRI, is derived from an average of color shifts for 8 color test samples. Since the shifts are treated irrespective of their direction, CRI exclusively estimates color fidelity.

Alternative Metrics for Color Rendition

However, color fidelity turns out to be an insufficient criterion for the subjective rating of color rendition, which is also related to the judgment on how "vivid" the colors look. To resolve the problem, Mark Rea and Jean Freyssinier-Nova from Lighting Research Center, Rensselaer Polytechnic Institute (RPI LRC) suggested a two-metric system comprising the general CRI and gamut area index (GAI). The latter Figure of merit measures the area of the polygon embraced by the chromaticity points of the same eight test color samples used by the CRI. This Figure of merit serves as a predictor of color discrimination [2].

Wendy Davis and Yoshi Ohno from NIST attempted to quantify the ability of a light source to render object colors with high fidelity and to discriminate colors within an integral Figure of merit, the Color Quality Scale (CQS) [3]. In comparison to CRI, the CQS metric contains numerous important refinements, such as the use of more perceptually uniform CIELAB color space, improved scaling and averaging procedures, as well as an advanced chromatic adaptation transform. The main idea of CQS is to disregard increased color saturation in measuring color shifts of the test color samples. This approach avoids penalizing the color discrimination ability; however, the resulting Figure of merit conceals the information on true color fidelity and does not completely distinguish between light sources having different ability in saturating object colors. To mitigate this drawback, CQS can be supplemented by appropriate color fidelity and color preference indices. However, this fix clashes with the initial idea of having one integral Figure of merit.

The three above metric suffer from a small number of test color samples used (8 to 15). Such a small number of colors covers a negligible portion of the color space and makes the assessment results dependent on the chosen set of the samples. Peter van

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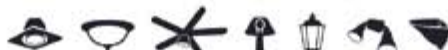
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der Burgt and Johan van Kemenade from Philips have addressed this problem by using a large number (215) of test color samples and analyzing the distribution of magnitudes and directions of color shifts (color-rendering vectors) [4]. Because of difficulties in averaging very different color-rendering vectors, they developed a graphic icon, which integrates information on both the magnitude and direction of the vectors. Such an icon provides experts with the extended color rendition information; however the end-users might find it difficult to understand and to use. Also, the icon is not very suitable for designing and optimizing light sources with predetermined color rendition properties.

Statistical Approach to Color Rendition

To mitigate the shortcomings of the above metrics, we recently introduced a statistical approach to assessing color rendition properties of light sources. Similarly to the Philips metric, this approach is based on a large and systematic set of test color samples, such as spectrophotometrically calibrated Munsell palette of 1269 samples [6], and employs color-shift vectors. The statistical approach also relies on several novel principles:

- Color rendering vectors are not more continuously quantified in magnitude and direction, but rather discretely grouped with respect to particular indices that score particular color rendition properties;
- Model color spaces are avoided (since they approximate the perceptually uniform color space with limited accuracy). Instead the color shift vectors are directly collated to data on chromaticity and luminance discrimination;
- The rating of light sources is presented in explicit numbers that are easy to understand for end-users and can be used for designing sources with predetermined and optimized color rendition properties.

The statistical approach works as follows. For each of 1269 color-shift vectors, a color discrimination shape is built and the color-shift vector is scored to a particular color rendition index depending on its behavior in respect to the shape. Each color discrimination shape is an elliptical cylinder (Figure 1). The cross-section of the cylinder is a triple-sized MacAdam ellipse, which is the region of the just-perceivable chromaticity difference. The half-height of the shape is three times the just-perceivable luminance difference (0.7%). Such a shape can be built for any test color sample by extrapolation of the original MacAdam data for 25 colors and quantifies color discrimination independently of a model color space used.

Each shape is centered at the color point of a test color sample under a reference illuminant. Then the reference illuminant is replaced by a light source under assessment, and the color-shift vector is analyzed and attributed to a particular group. If the color-shift vector resides within the shape, the color of the test color sample under a light source appears as almost indistinguishable from that under reference illuminant. In this case, the sample is scored to the statistical Color Fidelity Index (CFI).

Once a vector escapes from the shape, the sample is scored depending on the direction of the vector and its components. When the

vector has an excess component directed towards increased chromatic saturation, the sample is scored to the Color Saturation Index (CSI). Alternatively, when the vector is directed towards decreased chromatic saturation, the sample can be scored to the Color Dulling Index (CDI). Other indices, such as Hue Distortion Index or Luminance Distortion Index, can be introduced in a similar way.

The statistical indices are obtained computationally in the single format, which is the percentage of test color samples scored to each group. For instance for a light source that keeps 1015 vectors out of 1269 within the shapes and draws 114 vectors out of the shapes in the direction of increased chromatic saturation, the CFI is 70% and the CSI is 8%, respectively. Such a format has a very clear meaning and is easy to understand for an end-user. In contrast to the CQS metric and the graphical icon, explicit indices are easy to use in target functions for optimizing spectral power distributions of light sources with desired color rendition properties.

In most cases, two statistical indices, CFI and CSI, contain sufficient information for judging about the color rendition properties of a light source, similarly to RPI LRC two-metric system.

Table 1 summarizes the main features of different color rendition metrics.

Figure 1: Color discrimination shape for a test color sample used in the statistical approach to color rendition of light sources

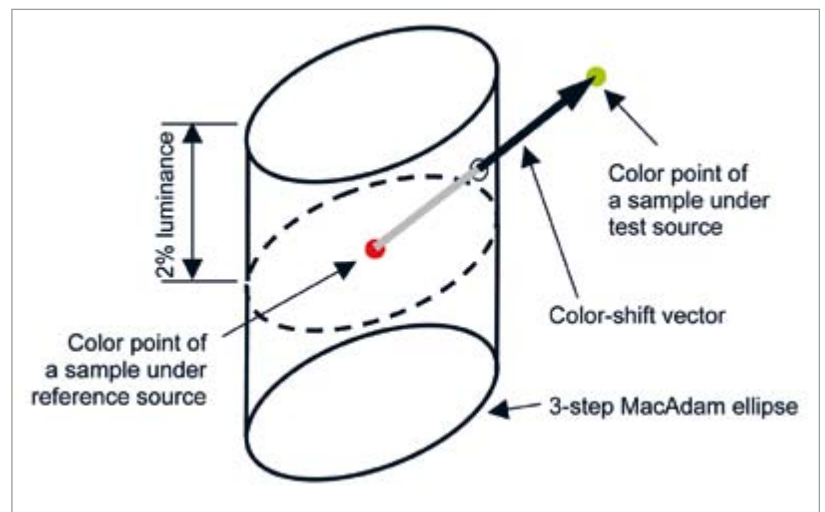


Table 1:
Comparison of color rendition metrics

	Number of samples	Model color space	Method	Main output
CIE CRI	8/14	U*V*W*	Averaging color shifts	Derivative index (the general CRI)
RPI LRC two-metric system	8	U*V*W*	Averaging color shifts and estimating gamut area	Two derivative indices (CRI and GAI)
NIST CQS	15	CIELAB	Averaging color shifts with the color-saturating component disregarded	Implicit derivative index (CQS) supplemented by other indices
Philips	215-5600	CIELAB	Analyzing color-shift vectors	Graphical icon
VU/RPI statistical	1269	Avoided	Grouping color-shift vectors	Explicit test sample percentage for any color rendition property

This classification is illustrated by Figure 2 that shows spectral power distributions of solid-state lamps with different statistical color rendition properties and corresponding color quality charts for 218 test color samples. Open points in the charts stand for colors rendered with high fidelity and arrows represent color rendition vectors that distort color saturation. The vectors that are directed toward the center of diagram show colors that are perceptually dulled and those directed outward the center show colors that have perceptually increased saturation.

Statistical Assessment of Solid-State Lamps

Table 2 presents some examples of statistical assessment of conventional and solid-state light sources [7].

Basically, the sources can be classified into three distinct groups depending on the spectral power distribution (SPD).

Sources with balanced SPDs having spectral components in the spectral ranges of both 530-610 nm and beyond 610 nm typically render more than 50% of test color samples indistinguishably from blackbody or reconstituted daylight illuminants. Such high-fidelity sources are incandescent/halogen lamps, multiband fluorescence lamps, phosphor conversion LEDs with at least three

spectral components and clusters of direct emission and pcLEDs containing at least four (red, amber, green, and blue) components.

Sources, which lack power in the 530-610 wavelength range, typically saturate more than 50% of test color samples and can be classified as color saturating lamps. An example of such a source is an RGB LED cluster.

Sources, which lack power for wavelengths longer than 610 nm, usually dull more than 50% of test color samples and can be classified as color dulling lamps. Examples of color dulling lamps are a dichromatic daylight pcLED (InGaN/YAG:Ce) and an AGB LED cluster. Such sources have both CFI and CSI low.

Conclusions

Many LED-based light sources have not only color fidelity but also color saturating and color dulling properties, and solid-state lighting technology needs an advanced color rendition metric. The statistical approach to color rendition offers a versatile and reliable assessment of color quality of illumination and allows for the development of light sources with predetermined and controllable color rendition properties. ■

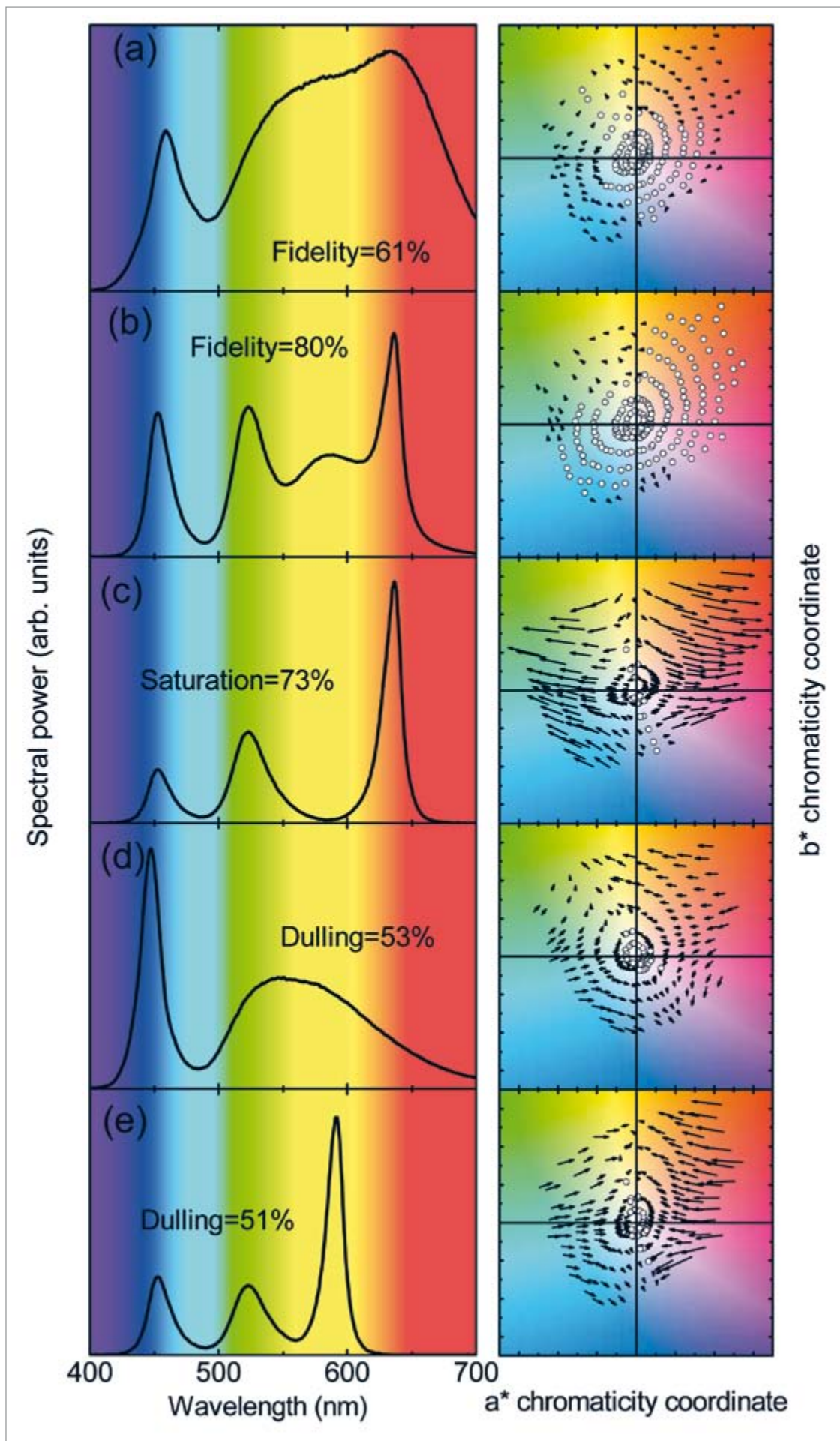
Table 2:
Statistical color rendition indices of some conventional and solid-state lamps [7]

	Color fidelity	Color saturating	Color dulling	Overall Ranking
Incandescent/halogen	100%	0%	0%	High-fidelity
Fluorescent halophosphate	12-26%	0-1%	53-72%	Dulling
Fluorescent multiband	92-96%	2-7%	0-9%	High-fidelity
Daylight pcLED (monophosphor)	17%	4%	53%	Dulling
Warm white pcLED (diphosphor)	61%	0%	25%	High-fidelity
RGB LED cluster	9-10%	67-80%	0-2%	Saturating
AGB LED cluster	12-24%	0-1%	51-67	Dulling
RpcAGB LED cluster	77-88%	1%	3-4%	High-fidelity

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Figure 2: Spectral power distributions (left) and color quality charts (right) of solid-state lamps with different statistical color rendition properties. High-fidelity lamps: warm-white pc LED (a) and RpcAGB LED cluster (b); color-saturating RGB LED cluster (c); color dulling lamps: daylight pc LED (d) and AGB LED cluster (e)



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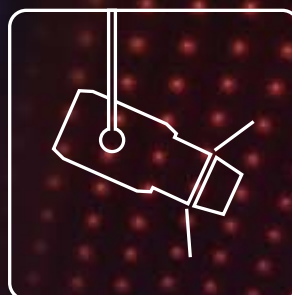
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Sophisticated LED Driver Enhances Quality in Full Color Video Displays

Luigi Pistoni, Massimiliano Merisiso, Fulvio Lissoni, and Walter Trovo from ST Microelectronics describe the main requirements and explain how to achieve the requested performance for full color LED video displays.

The massive presence of LEDs in everybody's daily life is no longer something new and the impact of their ever-growing use across several market segments is a matter of fact.

Displays and signage represent one of those fields in which the diffusion of the LEDs is considerable. From monochrome to full color panels, LED solutions are widely employed in road signs, advertisement panels, indoor and outdoor video displays, etc. with different demands and complexity.

Full Color LED Video Display

Full color LED video displays are panels showing images and moving animation in millions of colors. Stadiums, building facades, shopping centers, television studios, etc. are all places where these displays are employed.

These large LED panels are typically used for advertisement, information, for reproducing sport or music events and so on.

Figure 1 shows a very simplified block diagram for a LED video display.

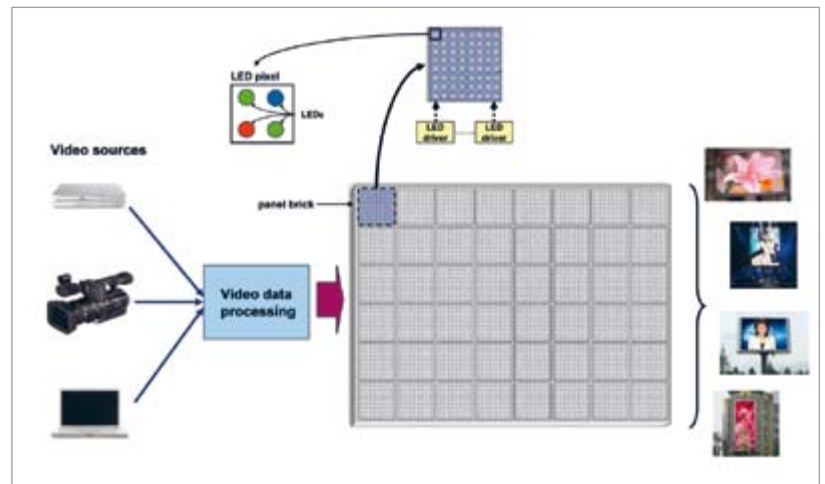


Figure 1: Simplified full color LED video display block diagram

The video input, provided by different type of sources, is conveniently processed before being sent to the LED display.

The panel is typically divided into square or rectangular bricks, each composed of several pixels. The pixel is made with RGB (red, green, blue) LEDs, whose color combination produces the desired pixel information. The LED driver represents the interface between the processed data and the colored light emitted by RGB LEDs (that, all together, compose the image).

Considering the target use of these large LED video displays, it is easy to realize the essential role played by the image quality.

This concept involves different aspects:

- Quality of the original image is surely a necessary starting point to achieve a good final result together with the data processing.
- Size of the panel, resolution, pixel pitch, and careful LED choice are all parameters that contribute to the image quality perceived by human eye.
- An appropriate LED driver capable of translating the processed image data into the desired chromatic and motion effects.

Since the target of this document is describing a LED driver solution for LED video display, the next sections will focus on the last aspect among the above mentioned ones.

LED Driver Requirements

In order to fulfill a high quality image in terms of chromatic and motion responses, a combination of different features is required: high frame rate, high refresh rate, accurate color reproduction, etc.

However quality does not only refer to the image itself, but also to the overall quality of the solution in terms of robustness, reliability, etc.

For these reasons full color LED video displays need the choice of sophisticated LED drivers:

- Good color rendering depends on the available brightness levels for each RGB LED (and so for each color): the more brightness levels available, the more color displayed. Proper and fine control of the brightness means the capability of performing a PWM dimming over a high number of levels.
- High frame and high refresh rates are concepts related to the possibility to deal with large amount of data at high speeds. The LED driver can meet these demands with a high frequency serial interface and flexibility in managing different data formats.
- A fault in one or more LEDs skews the pixel color, jeopardizing the result of the overall image and altering the perceived quality of the system. A reliable method for detecting LED faulty conditions is essential for preserving the desired effect on the video display.

A LED Driver Solution

In the wide family of LED drivers for display and signage in the STMicroelectronics portfolio, the STP1612PW05 (see Figure 2) is tailored for full color LED video displays.

The device is a sixteen channels LED driver with high frequency serial interface. Each channel can drive a current up to 60mA, programmable through an external resistor and accurately adjustable over 256 levels using an 8-bit gain register.

The increasing current accuracy at lower currents (typical $\pm 1.5\%$ between channels) goes in the same direction with the LED technology improvements in terms of luminous efficiency. In fact, the availability of LEDs more and more efficient makes panel makers use lower currents to achieve same brightness levels.

The device has an individual adjustable PWM brightness control for each output channel. The well-known PWM dimming advantages in LED color preservation together with the high number of brightness levels, selectable between 4096 (12 bit) or 65536 (16bit), result in enhanced color shading and improved video quality.

Further improvement of the dimming control is achieved by using the scrambled PWM mode. Essentially the total PWM cycles are spread over many refresh cycles. The effect is like having a higher dimming frequency keeping the same dimming resolution, bringing a reduction of the flickering.

The characteristics of the integrated serial interface of STP1612PW05 comply with demands of high data rate and speed of video display as well as flexibility in data format: data can be sent at a clock frequency up to 30MHz, in 16x16bit format (or 16x12bit in case of 4096 brightness levels selected) or the more compressed 256bit format.

As already mentioned, a robust and reliable application significantly contributes to the overall quality of the system.

The detection of faulty LEDs (open or shorted) performed by the STP1612PW05, whose results are provided through the serial interface, avoids a color change or a switch off of the involved pixels, preserving the image integrity.

The simultaneous turning on of all LEDs at the start of a video frame causes a relevant inrush current with very steep rising edge, implying large input capacitors, ringing due to parasitic paths and noise in the system. This current can be considerably reduced by staggering the turn on phase of the channels with a progressive delay of 40ns between each group of outputs composed of four consecutive channels (first OUT0, OUT1, OUT2 and OUT3 then OUT4 to OUT7, and so on).

The accidental unavailability of the PWCLK signal (the clock that feeds the PWM counter for the PWM dimming control) for any reason (e.g. wire disconnection) can keep all LEDs of the video display indefinitely on.

This event, apart from preventing the correct image visualization, can be hazardous for LEDs, which can overheat or get damaged. A PWM

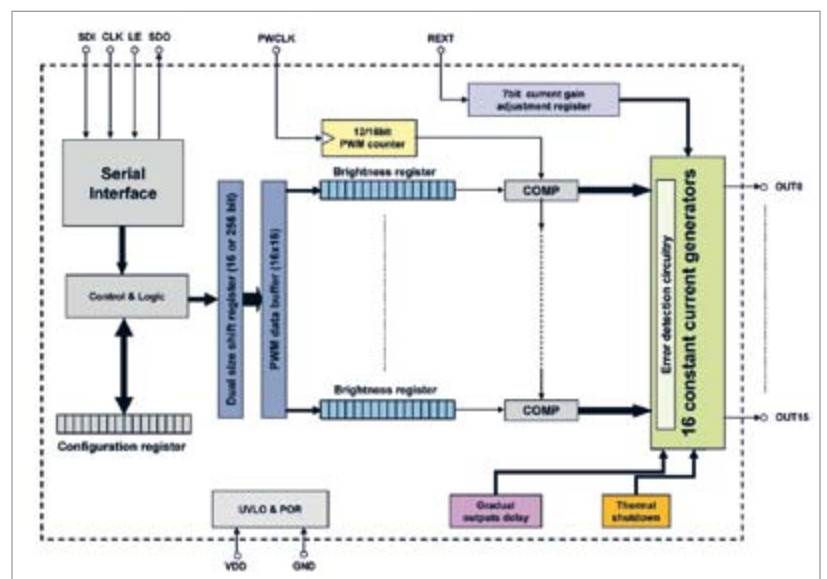


Figure 2: STP1612PW05 simplified block diagram



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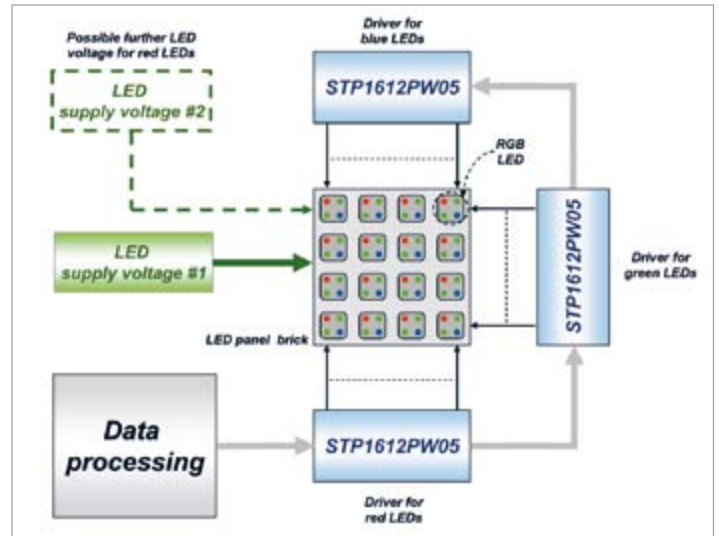


Figure 3: STP1612PW05 driving a full color LED video display brick

clock timeout disconnection can be activated in STP1612PW05: generators are forced off in case of PWCLK signal absence for at least one second.

Application Example

The LED forward voltage and the programmed current to achieve the target brightness vary with LED colors: red LEDs are characterized by a lower forward voltage compared to green and blue ones, whereas blue LEDs are typically driven with lower currents. These considerations bring to the recommendation of using a different driver for each color.

A panel brick is composed of 16 pixels, each built with four colored LEDs (one red, two green, one blue).

Sixteen LEDs of the same color are driven by one STP1612PW05 (see Figure 3).

The choice of the LED supply voltage (VLED) is typically a trade-off between often opposing demands.

VLED should be high enough to correctly keep the LEDs on, but low enough to minimize the

voltage drop across current generators of the LED driver, which causes useless loss of power and consequent heating of the ICs and of the system.

Evidently the presence of a single VLED for red, green and blue LEDs is not the best solution. An optimization of the LEDs supply voltage is desirable and can be accomplished by separating LEDs voltage rails.

This implies the adequate driving of all LEDs and saving power at the same time.

Conclusions

The demand of high quality image in full color LED video displays poses new challenges in the choice of the appropriate LED drivers.

Excellent performance in color reproduction and minimization of video artifacts are essential requirements of these applications.

A dedicated STMicroelectronics LED driver provides a high quality solution capable of matching the full color LED video display demands. ■

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Cooling High Power LEDs

Norbert Engelberts, Director at Advanced Thermal Solutions explains how to develop a cooling solution based on an independent analysis approach, i.e., analytical, experimental and computational, that provides the designer with a high degree of confidence.

Light-emitting diodes (LEDs) have long been used in instruments and computers as visual indicators for signal integrity and operations status. LEDs are ideal choices due to their high reliability, low power use and little to no maintenance needs. More recent market interest in LEDs is in their use not only as indicators, but also as lighting devices. However, as illumination becomes the focus, the power consumption of LEDs has risen dramatically. Device heat fluxes are rivaling those of CPUs and other semiconductor packages. As a result, the thermal management of LEDs has taken center stage for their successful implementation.

It is important to remember that an LED is not a high temperature, filament-type lighting device. While a single LED is a cold and efficient light source, high-power LED applications, including arrays of LEDs, need thermal management similar to other semiconductor devices. High temperatures not only degrade an

LED's lifetime, but also result in lower or non-uniform light output, which can significantly affect their application.

Most LEDs are designed in SMT (surface mount technology) or COB (chip-on-board) packages. In the new 1~8 W range of surface mount power LED packages, the heat flux at the devices' thermal interface can range from 5 to 20 W/cm². These AlInGaP and InGaN semiconductors have physical properties and limits similar to other transistors or ASICs (application specific integrated circuits). While the heat of filament lights can be removed by infrared radiation, LEDs rely on conductive heat transfer for effective cooling.

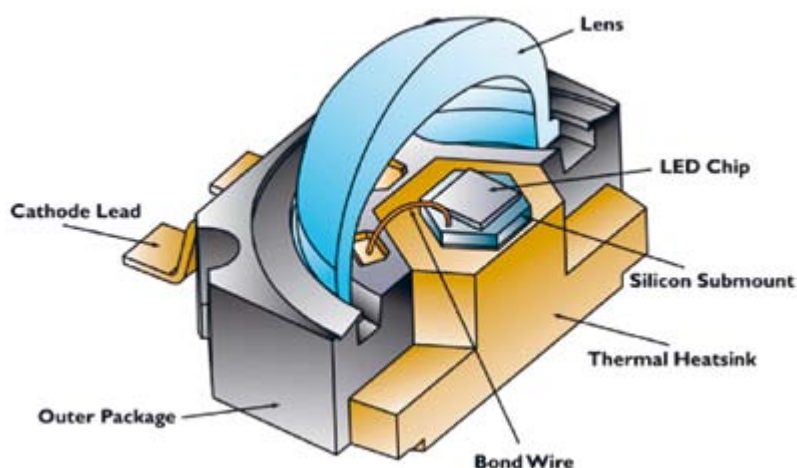
As higher powers are dissipated from LED leads and central thermal slugs, boards have changed to move this heat appropriately. Standard FR-4 technology boards can still be used for LEDs with up to 0.5 W of dissipation, but metallic substrates are required for higher levels. A metal core printed

circuit board (MCPCB), also known as an insulated metal substrate (IMS) board, is often used underneath 1W and larger devices. These boards typically have a 1.6 mm (1/16 inch) base layer of aluminum with a dielectric layer attached. Copper traces and solder masks are added subsequently. The aluminum base allows the heat to move efficiently away from the LED to the system [1].

But, thermally dissipating PCBs are not always adequate or suitable for LED applications. Other cooling design choices are available, and it can be challenging to select the most appropriate and cost effective solution for a given application. In this article we show the required approach for the thermal management of LEDs. This method enables the designer to select the appropriate cooling solution based on the LED's junction temperature, and not on the total power dissipation.

Two parameters play a pivotal role in the success of an LED. These are the cooling method and the optical lens. These factors affect the shape, size, and construction of the luminaire that comprises the overall lighting unit. Because long life and fail-safe operation are essential for any LED, the cooling process is uniquely critical. An LED's plastic body is not thermally conductive, and the device does not radiate heat. The only effective cooling method is to conduct the heat away through the bottom of the device. Therefore, highly thermally conductive materials are commonly used to take the heat from the LED's back side (see Figure 1). Depending on power dissipation and light emission uniformity, the method of cooling can

Figure 1:
Luxeon K2 Power LED (courtesy of Lumileds).



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be passive (heat sink in natural convection) to active (fan-sinks), or can use liquid cooling.

With their basic, robust construction, LEDs can be used in environments ranging from ornamental to such critical illumination needs as automotive headlamps. Therefore, their cooling systems must be designed with the ambient temperature and the specific end use in mind. For example, a car's headlamp with an under-the-hood temperature of 85-100°C and power dissipation values of 42-90 W requires unique consideration for cooling and reliability. In other applications, to get the same light output as an incandescent lamp, the LED lamp will often run on comparable power dissipation values. However, the LED device's maximum allowable junction temperature is limited to 120-135°C (up to 185 °C in recent developments). If we compare these limits to an incandescent lamp, which allows filament-operating temperatures of 1500-3000°C, the thermal challenge for LEDs, especially in harsh environments, is the major obstacle to their successful implementation.

These thermal constraints typically need to be considered:

- T_{junction LED max.} < 120-185°C
- T_{junction LED lifetime} <100~110°C
- P_{LED} = 1-8 W
- Light output is strongly dependent on temperature

Figure 2:
A maxiFLOW
linear heat sink for
cooling LED strips



Figure 3: An LED-based spotlight with around finned heat sink. Visible and IR views

Cooling Options

For LEDs, cooling options range from simple natural convection in air to liquid cooling where a cold plate and liquid loop form the required cooling system. Because most market applications for LEDs shy away from liquid cooling, the focus of this section will be on air-cooling of LEDs.

Most LED lamps employ familiar heat sinking techniques. In some cases, the metal fixture of a luminaire can act as a heat sink, but the thermal requirements of its LEDs must be considered when designing the unit. Increasing power density, a higher demand for light output, and space constraints are leading to more advanced cooling solutions. High-efficiency heat sinks, optimized for convection and radiation within a specific application, will become more and more important.

Thermal resistance plays a significant role in the thermal management of LEDs. Outside of the sink-to-air thermal resistance, the highest thermal resistance in the heat transfer path is the junction-to-board thermal resistance (R_{j-b}) of the package [2]. Spreading resistance is also an important issue. Thermally enhanced spreader materials, such as metal core PCBs, vapor chambers and cold plates and for high heat flux applications are viable systems to reduce spreading resistance [3]. Metal core PCBs are generally used for LED applications. With the constraints in space for fan applications, metal core PCBs can be used effectively to conduct a major portion of the heat through the board. Vapor chambers bonded to the bottom of heat sinks have been used successfully to spread heat. Alternative to bonding, heat sink fins can be directly brazed onto a chamber. Cold plates are the most expensive solutions and are typically used for higher heat flux applications. Difficult to apply, they require liquid flow, which in turn requires a pump and associated plumbing.

For cooling LED strips, where the above heat spreaders are impractical, specially designed linear heat sinks are available. For example, some linear LED strips used in architectural lighting are cooled with linear heat sinks that feature a spread fin array design for more effective cooling, particularly when air flow is limited, such as inside display cases.

These heat sinks typically feature a low profile, spread fin array that maximizes surface area for more effective convection (air) cooling. The heat sink is fabricated from extruded aluminum, which minimizes thermal resistance from the base to the fins and reduces weight. Tests on spread fin array designed heat sinks using a low air flow rate show a reduction in LED temperatures by more than 50%.

Round heat sinks are available specifically for round LED boards, which are used to replace halogen light bulbs, in applications such as spotlights and down lighting. A typical LED spotlight is shown in Figure 3 [4]. Here, a round heat sink is used for cooling three LEDs. The round heat sink has a star-shaped profile fin design that maximizes surface area for more effective convection (air) and radiation cooling in the vertical mounting orientation, e.g., inside ceilings.

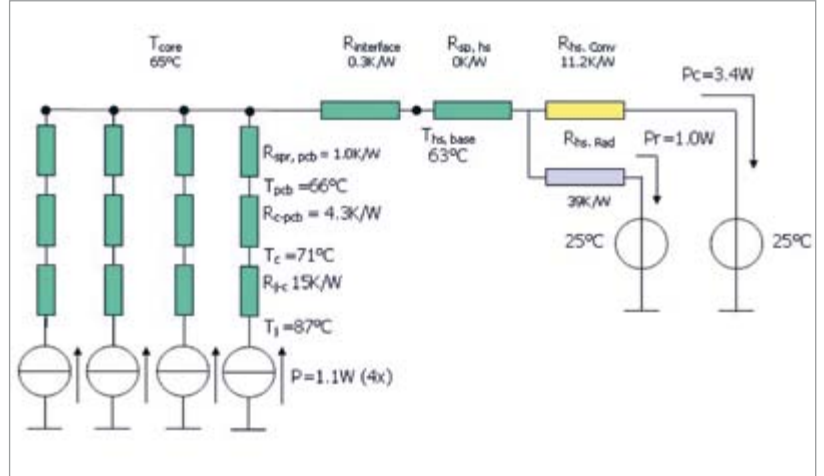


Figure 4: Electrical analog of an LED lamp

Active thermal management systems can be used for high-flux power LED applications. These include water cooling, two-phase cooling, and fans. If well designed, the lowered T_j from an active cooling solution can increase the efficacy of an LED to a level that easily compensates the power usage

of the active system while increasing lumen output. A successful thermal management system can also allow maintenance-free operation or continued achievement of specific wavelength requirements.



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Switch ON Resistance (Typ.)		0.45Ω	0.45Ω	0.3Ω	0.3Ω	0.3Ω	0.3Ω	0.3Ω
Dimming Method	Digital	•	•	•	•	•	•	•
	Analog			•				
	Panel Switch				•			
Protection	LED Open- / Short-Circuit	•	•	•	•	•	•	•
	Thermal	•	•	•	•	•	•	•
	Start-Up	•	•	•	•	•	•	•
	UVLO	•	•	•	•	•	•	•
RoHS Compliant Package	OCP			•	•	•	•	•
	TO252	•					•	•
	SOP8			•	•		•	•
	MSOP8	•	•		•	•		
Major Applications	SOT89							
	SOT23	•	•					
Major Applications		MR11, MR16, Flood Light, PAR Light, Wall Wash Light, Emergency Lighting, Street Light, Tunnel Lighting, High Power LED Lighting						

The LED Thermal Design and Cooling Solution Selection Process

The thermal design of any electronic component, including an LED, consists of three steps [5].

- Analytical (Integral) Analysis
- Computational (Numerical) Analysis
- Experimental Analysis/Verification

Analytical Analysis

Analytical analysis is used to develop a first-order solution. This approach identifies the problem areas (components and system layout) and ascertains the magnitude of the problem (device junction temperature and required level of cooling). Some analyses can be performed quickly to get a handle on the scope of the problem – the so-called “what if” scenario.

The MCPCB is mounted onto the base of a round heat sink using a double-sided, thermally conductive tape. This interface adds a theoretical thermal resistance of 0.3 K/W to the network. The spreading resistance within the base of the heat sink is expected to be zero since the respective areas are the same. Heat is removed from the sink's base and fins by natural convection and radiation heat transfer.

With the total thermal network in place, the junction temperature can be calculated for a specified ambient. When the LEDs are operating on 1.1 W, the junctions are within specification. In this set-up, radiation heat transfer is contributing 23% and must be included in the analysis. For natural convection cooling, the performance of the heat sink will differ based on the power supplied to the LED.

Computational Analysis

Computational analyses were used to develop the second-order solutions to verify results from step 1. The problem must be well understood in order to develop a model that accurately represents the problem.

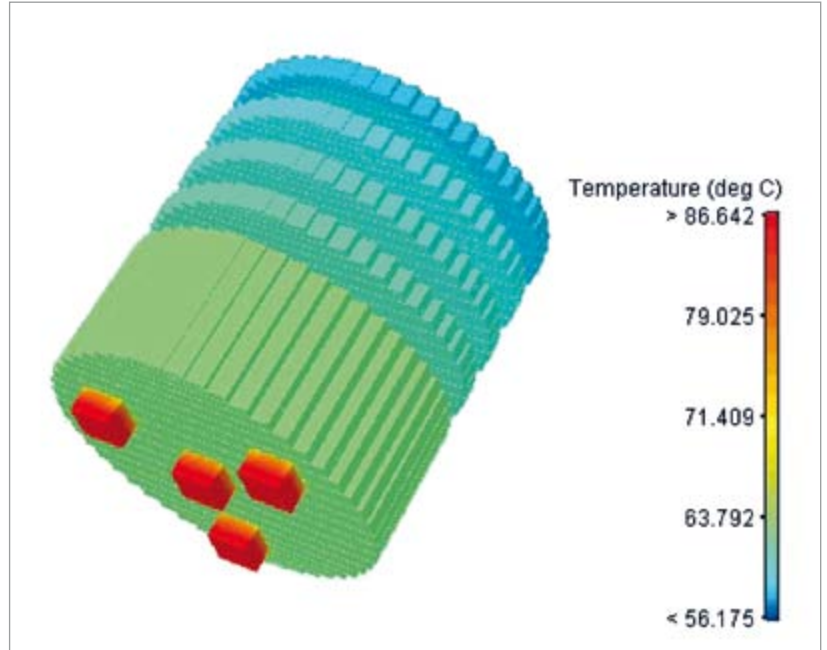


Figure 5: Results of the CFD study.

CFD was used to characterize the spreading resistance, flow around the LED lamp, and heat sink performance. Figure 5 shows the results of the CFD study on the LED lamp. The LEDs were represented by compact 2 resistor models. The effect of the glue layer interface was added to the Rj-b (thermal resistance from the chip to the heat carrying layers of the PCB). A detailed model was used for the board to accurately represent the effect of spreading resistance. The heat sink was modeled in greater detail. The result of the analysis is shown in Figure 5 and Table 2.

Experimental Analysis/Verification

For this LED-based spotlight application, the junction temperature was measured by the forward voltage characteristic. All four LEDs are calibrated with a current source of 10 mA. During the operational test, the current measurement source is on all the time, and, after stabilization, the operational current is switched off. After switching off the operational current, the drop in forward voltage is measured with a memory oscilloscope. The thermal mass of the junction is small, which results in a fast

cool-down time. This temperature change occurs in less than 1 msec; the forward voltage has to be measured in microseconds after the event.

More background information can be found in Farkas, et al. [6].

Table 1 shows the measurement results, and Table 2 presents the results of all three analysis methods. The measurements offer a good comparison of the analytical/computational methods; and the error factor is within 16%. The interface resistances and thermal spreading showed higher values in the experiment. Interface resistances are theoretically difficult to predict. Only an actual experiment can give the final answer and take account of manufacturing deviations.

Considering the LED's junction temperature limit of $T_{\text{junction LED max.}} < 120^{\circ}\text{C}$ and the calculated/measured junction temperatures shown in Table 2, the results show ample design margin. Therefore, the selected cooling solution (heat sink) is suitable for this application and there is no need to consider a higher capacity system.

Table 1:
Measurement results

Measurement	Unit	LED 1	LED 2	LED 3	LED 4
LED	na	LXHL-BW03	LXHL-BW03	LXHL-BW03	LXHL-BW02
Color	na	Warm White	Warm White	Warm White	White
Tambient	°C	21.6	21.6	21.6	21.6
Tbase hs	°C	61.4	61.6	60.9	61.0
Tpcb, copper below slug	°C	66.8	65.9	66.7	66.2
Uf, oper+meas.	V	3.214	3.098	3.105	3.159
If, oper+meas.	A	0.350	0.350	0.349	0.350
Pled, in	W	1.12	1.08	1.08	1.11
% to light		2%	2%	2%	3%
Pled, oper	W	1.10	1.07	1.07	1.08
mV operational-measured	mV	680	564	568	616
Uf, test, hot	V	2.534	2.534	2.537	2.543
If, test	A	1.00E-2	1.00E-2	1.00E-2	1.00E-2
Tjunction	°C	94.5	91.5	89.3	93.7
Rj-b	K/W	24.3	24.0	21.2	25.5

Table 2:
Overview results of the three methods

Parameter	Temperatures corrected [°C]		
	Analytical	Numerical	Experimental
Ambient	25	25	25
Heat Sink base	63	63	65
Metal Core	65	64	Not measured
PCB below LED	66	65	70
Junction	87	87	96

Conclusion

Thermal management is vital to the successful implementation of LEDs. Selecting a cooling solution based on device (LED) junction temperature ensures that the most critical parameter, one that can adversely impact its reliability and performance, is identified and thermally managed. More importantly, developing a cooling solution based on an independent analysis approach, i.e., analytical, experimental and computational, provides the designer with a high degree of confidence while enabling the designer to select the most effective cooling solution for the high power LED. ■

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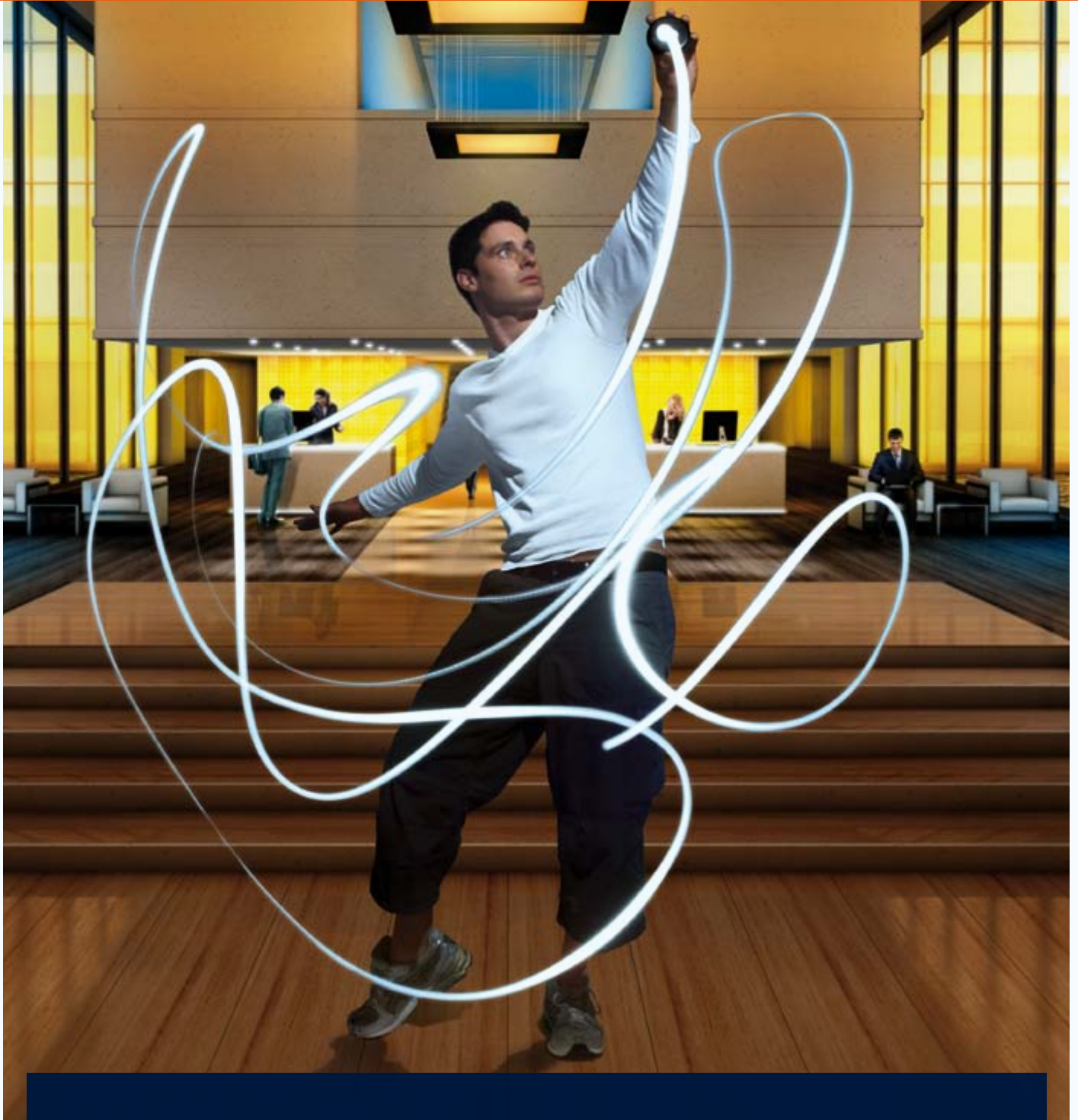
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